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MODERN GUNS AND GUNNERY

BY

LT COLONEL H. A. BETHELL

R.F.A.

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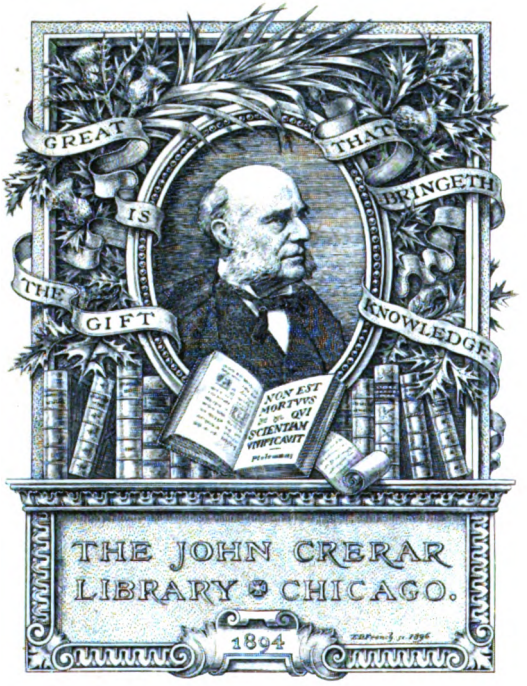

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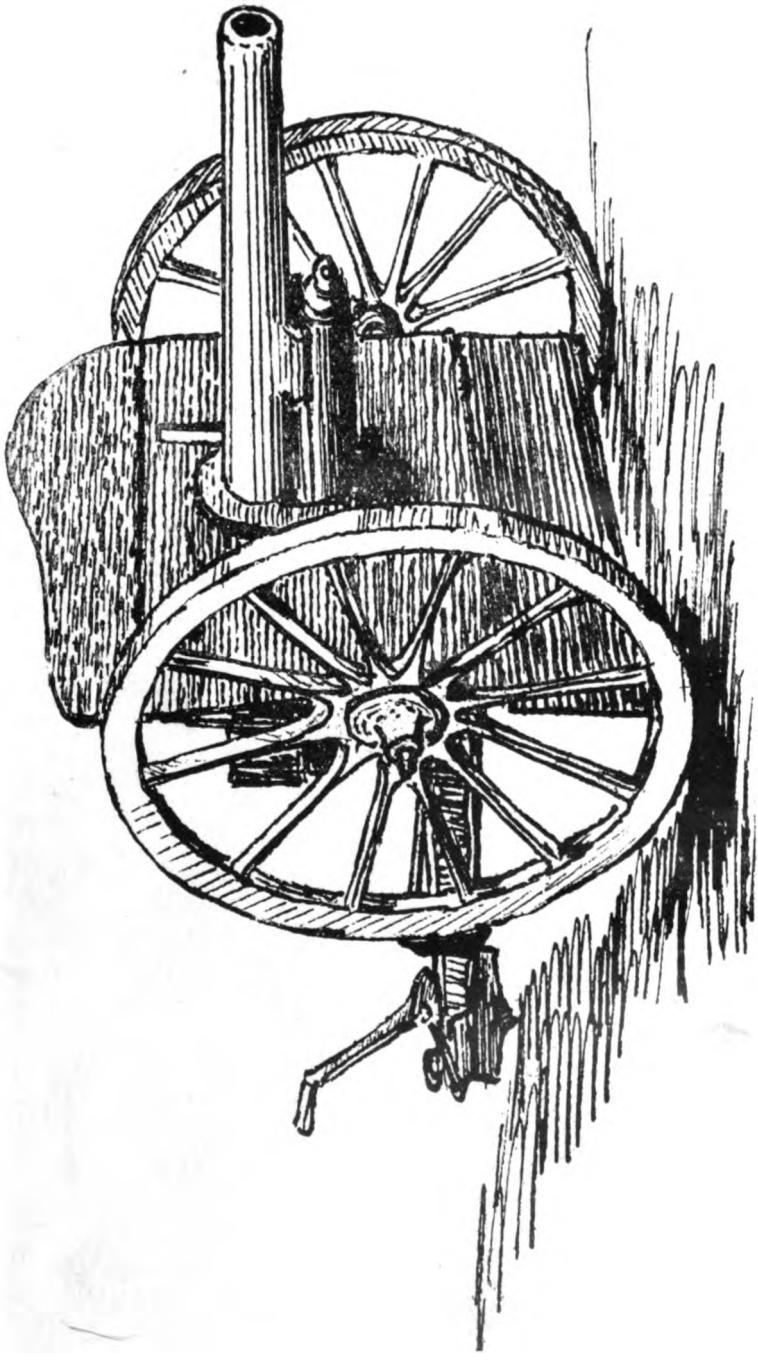

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THE
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MODERN GUNS AND GUNNERY, 1907.

A PRACTICAL MANUAL

for Officers of the

HORSE, FIELD and MOUNTAIN ARTILLERY.

By LT.-COLONEL H. A. BETHELL,
Royal Field Artillery.

WOOLWICH:
F. J. CATTERMOLE,
WELLINGTON STREET.
1907.

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PREFACE TO FIRST EDITION.

The Official Text Book is probably the most perfect treatise on Gunnery now existing in any language. Many officers are, however, deterred from studying it by the real or imaginary terrors of the mathematical demonstrations with which its pages bristle.

For officers whose business it is to design and to make guns, carriages and ammunition, an exact mathematical knowledge of the science of Gunnery is indispensable; but for officers who have to use the gun it is sufficient to have a clear understanding of the principles of Gunnery, in order that they may be able to apply these principles to the best advantage in handling their guns.

Thus, it is not necessary that a Field Battery Commander should know how to calculate the strains in the buffers of his guns, but it is most desirable that he should know that his shrapnel bullets cover a wider front at a long range than at a short one, if burst at the same distance from the target, and why this is so.

This book is intended to serve two purposes: first, as an easily understood manual for those whose daily duty leaves them no time to attack and thoroughly master such a difficult science as Gunnery; and secondly, it is intended as an introduction to the study of more advanced books. Many of the facts stated in this elementary manual have to be accepted without proof, as, for instance, Barlow's Law, and it is hoped that many readers will be dissatisfied with such unsupported statements and will be at the trouble to read up the demonstration of them in more scientific books.

The general scheme of this book differs in one respect from that of previous treatises on the same subject. Hitherto the science of Gunnery has been held to include only theoretical ballistics and the theory of gun construction. But with the advent of the Q.F. gun the principles of the design of the carriage and of the ammunition have assumed an importance at least equal to those governing the design of the gun; and a sound knowledge of these principles is indispensable both to the officer who designs the equipment and to his comrade who has to use it.

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PREFACE TO SECOND EDITION.

Since the first edition of this book was issued, the development of the quick-firing gun has proceeded with extraordinary rapidity. All the military nations of the world have adopted Q.F. field guns, and re-armament with Q.F. howitzers and mountain guns is now proceeding. The principles of construction remain unchanged, but the improvements which have been introduced have rendered it necessary to re-write the whole of the sections dealing with guns, carriages, and ammunition, and with English and foreign Q.F. equipments.

In the domain of practical gunnery, the principal change has been the adoption of a more elastic system, enabling battery commanders to use the novel fire-tactics introduced by the French without abandoning the older and more deliberate methods.

In view of the general adoption of fire from the covered position as the normal method, fresh chapters have been added dealing with the theory and practice of Indirect Fire.

The book has been considerably enlarged, and numerous plates of English and foreign equipments have been added.

H. A. B.

Aldershot,
1.5.07.

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Errata and Addenda to 1st June, 1907.

Page 18.—The goniometric sight is now styled in our Service the "dial sight."

Page 23.—Colonel Scott's "automatic" independent line of sight gear also eliminates drift and difference of level of wheels. See page 303.

Page 41.—The action of running-up springs is further considered in Chapter XXX. See page 256.

Page 47.—The later Ehrhardt guns are not pivoted on the axle-tree. See page 261.

Page 57.—Nitro-guanidin is a new nitro powder with which finely-divided carbon is mechanically incorporated. It is claimed that it gives low temperatures in the bore.

Page 58.—The composition of ammonal is now given at 75 ammonium nitrate, 5 carbon, and 20 aluminium.

Page 64.—The Swedes are trying the Holmgren shrapnel with bullets set in smoke composition.

Page 68.—The Ehrhardt H.E. shrapnel, 1907 pattern, has the H.E. charge in the fuze instead of among the bullets. The useful weight is 47% as before.

Page 79.—The later Krupp howitzers have extreme rear trunnions and a constant recoil of 48 inches. See page 271.

Page 89.—The M.V. of the mountain howitzer should be 900 fs., not 700 fs., and the calculation should be revised accordingly. See page 114.

Page 172, Note.—F.A.T. 1907 allows sweeping at any rate of fire.

Pages 189, 206.—The corrector is now graduated to 300, with 150 in the centre.

Page 189.—Fuze Ladder.—F.A.T. 1907 directs that "increase 10" is to be ordered, giving the first burst of the ladder in air and the last on graze.

Page 228.—The Russian 1903 equipment has the pole, limber hook, and draught-loops set in india-rubber block springs, and the ammunition boxes are on india-rubber blocks.

This reform is most instructive as being the result of the experience of a long campaign.

Page 233.—The Austrian gun is further described on page 252.

Page 236.—The Schneider Spanish and Portuguese equipments have spring draught and spring limber hooks.

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Part I.

PRINCIPLES OF CONSTRUCTION

OF

GUNS, CARRIAGES, AND AMMUNITION.

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CHAPTER I.

INTERNAL BALLISTICS.

Gunnery.

Gunnery is the science of directing a projectile so that it will strike a given target.

To master the science it is necessary to understand the general construction of the gun and carriage and the cartridge which jointly impart the motion to the projectile, and the working of the laws which govern this motion.

The Gun.

The gun serves two purposes. First, to confine the powder-gases so as to allow them to act upon the base of the shell; and second, to give the shell the proper direction.

As the powder charge burns, it is converted into gas of greatly increased volume. This gas, in its endeavour to expand, presses upon the base of the shell and drives it up the bore. So long as it continues to exert a forward pressure upon the base of the shell, it continues to accelerate the motion of the shell, and the velocity of the latter goes on increasing until it passes out of the muzzle, and the pressure on its base ceases.

Capacity of Gun.

We should get the greatest possible effect out of a charge of powder if the gun were made long enough to contain the whole of the powder gases, so that the forward pressure on the base of the shell would cease just as the shell reached the muzzle. Such a gun would however be unwieldy, and in practice we cut the gun short and allow a good deal of the gas-pressure to go to waste out of the muzzle.

Length of Gun.

The length of a modern gun varies from 25 calibres for field guns up to 50 calibres for long naval guns. The usual length of the bore of a field gun is from 30 to 32 calibres. A *calibre* is the diameter of the bore, measured between opposite ribs of the rifling, not down to the bottom of the grooves between the ribs.

Thus the length of the bore of a 28-calibre 3-inch field gun would be 3×28 inches or 7 feet.

Pressure in Bore.

Thirty years ago the only explosive used in guns was coarse black powder. The whole of the charge was converted into gas almost

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immediately on ignition, thus developing a very heavy pressure in the powder-chamber, which rapidly fell as the shell moved up the bore. Guns of this period were therefore made of a very pronounced bottle shape, enormously thick at the breech.

As an improvement on this, pebble powder was devised. This consisted of cubical grains of from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches. These burnt more slowly, giving a less pressure at the start and a better-maintained pressure as the shell travelled up the bore. Guns were then made thinner at the breech and thicker towards the muzzle.

Prismatic powder, pressed into large six-sided prisms, was the next step; this was followed by slow-burning brown powder, known as cocoa powder.

Now we have smokeless powder, in thick cords, tubes or tapes for long guns and fine strings for short ones. This has enabled us to adjust the pressures in the bore so as to get the maximum of work out of the gun with the minimum of metal.

Curves of Pressure.

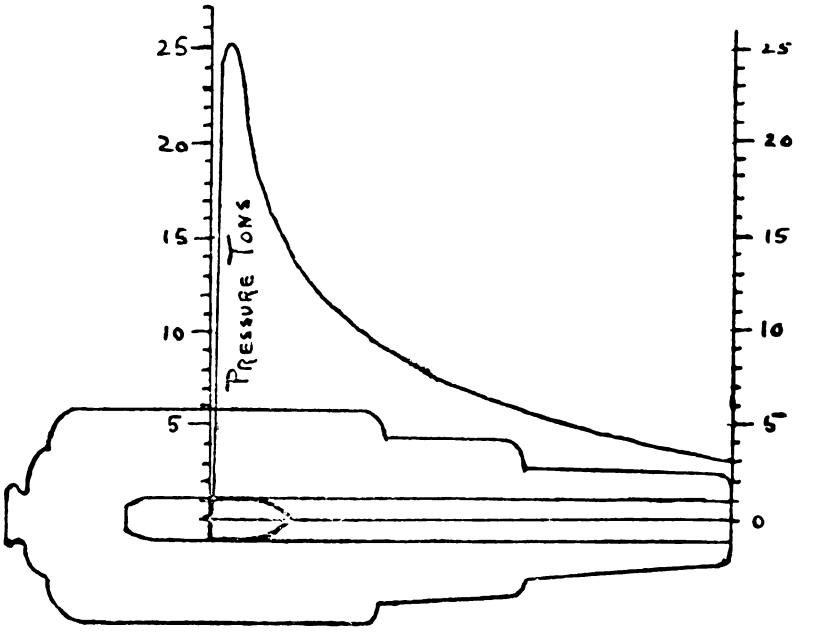

FIG. 1.

A simple and convenient means of showing graphically the pressure in any gun is by the use of pressure curves.

Fig. 1 gives the curve for the 12″ R.M.L. gun, using black powder.

Here the height of the curve represents the pressure in tons at that particular point in the bore. We note how the pressure rises from 0 to 24 tons per square inch before the shell begins to move, and runs up to 25 tons before the shell has travelled half its length. The pressure then rapidly falls till at the muzzle it is only 3 tons per square inch.

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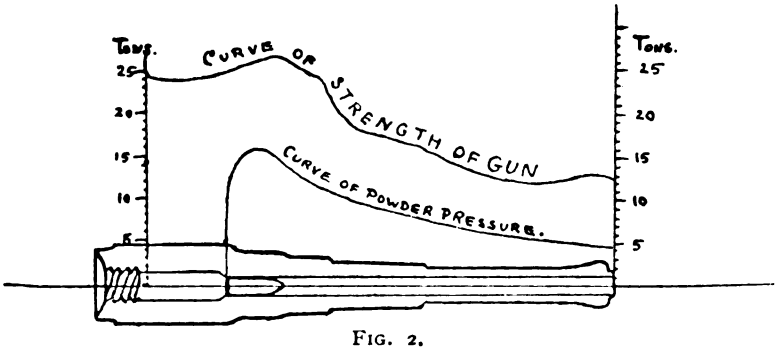

FIG. 2.

As a contrast to this, the curve for the 6 inch Q.F. gun (Fig. 2) shows a pressure which nowhere exceeds 15 tons on the square inch and which diminishes gradually towards the muzzle. We may also note how in each gun the shape or profile of the gun corresponds with the curve of powder-pressure.

Crusher Gauges.

To discover the amount of the pressure at different points in the bore by practical experiment, crusher-gauges are used.

An experimental gun is bored with holes say a foot apart all the way down, extending through into the bore. Into each hole is screwed a crusher-gauge, consisting essentially of a piston with a soft copper plug behind it. As the shell travels up the bore each piston in turn is exposed to the pressure of the gases and forced back, compressing the plug behind it. By measuring the amount of the compression of each plug the pressure to which it was exposed can be determined with remarkable accuracy.

Noble's Chronoscope.

The crusher-gauges afford a means of measuring the pressure at any point in the bore. To measure the velocity, the chronoscope is used.

Instead of the crusher-gauges, cutter plugs are inserted into the holes in the gun. Each plug has an electric wire passing through it, and a knife, of which the back projects into the bore. When the shell passes the plug it forces in the knife and cuts the wire. This interruption of the circuit causes an electric spark to pass at another point in the circuit.

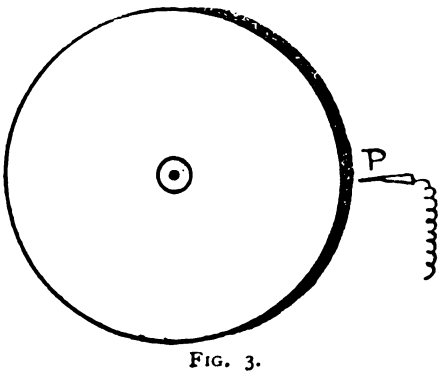

FIG. 3.

To record the instant at which this takes place, a brass disc some 30 inches in circumference is revolved at a great speed. The edge of the disc is smoked. Each interruption of current as the shell passes a cutter-plug causes a spark to pass between the point P and the disc, burning a hole in the coating of smoke-black. The velocity of rotation of the disc being known, it is only necessary to measure the

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distance between the marks left by the sparks to know the time that elapsed between them.

To avoid confusion, a row of discs fixed on the same axle, one for each cutter-plug, is used.

The Le Boulengé Chronograph.

This instrument is used for measuring the velocity of the shell after leaving the muzzle. Two screens are placed one behind the other in the path of the shell, say 80 feet apart, and sufficiently far off to be clear of the blast of the gun. Each screen has an electric wire stretched backwards and forwards across it so that when the shell passes through the screen the circuit is broken.

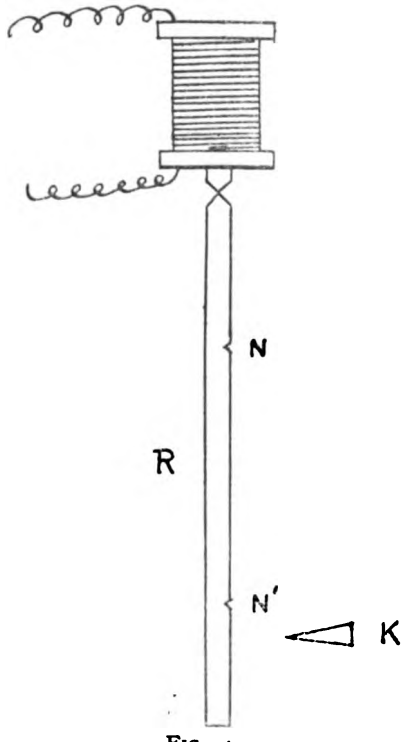

FIG. 4.

Let R be a rod suspended from an electro-magnet. When the shell passes the first screen the circuit is broken and the rod begins to fall. When the shell passes through the second screen the break of circuit releases the knife K, which makes a nick N on the falling rod. Since the force of gravity does not vary, the rod falls at the same speed every time, and it is only necessary to measure the distance of the nick up the rod with a suitable scale in order to know the time taken by the shell to travel from one screen to the other.

Disjunctor.

To allow for the time taken for the knife to act after the circuit is broken at the second screen, the disjunctor is used. This is simply a contrivance for breaking both screen-circuits simultaneously. The rod then falls a short distance before the knife has time to act, making a nick at N′. The distance NN′ is thus the true measure of the time taken by the shell between the two screens. The distance up the rod of the nick N′ is known as the *disjunctor reading*.

Sebert's Velocimeter.

This is a simple apparatus for measuring the velocity of recoil of a gun. A bristle fixed to a vibrating tuning-fork is made to brush against the smoked surface of a strip of steel attached to the gun. When the gun recoils, the bristle traces a wavy line on the smoked surface. Since we know the rate of vibration of the tuning-fork, it is only necessary to count the waves to determine the speed of recoil.

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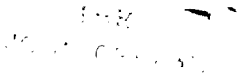

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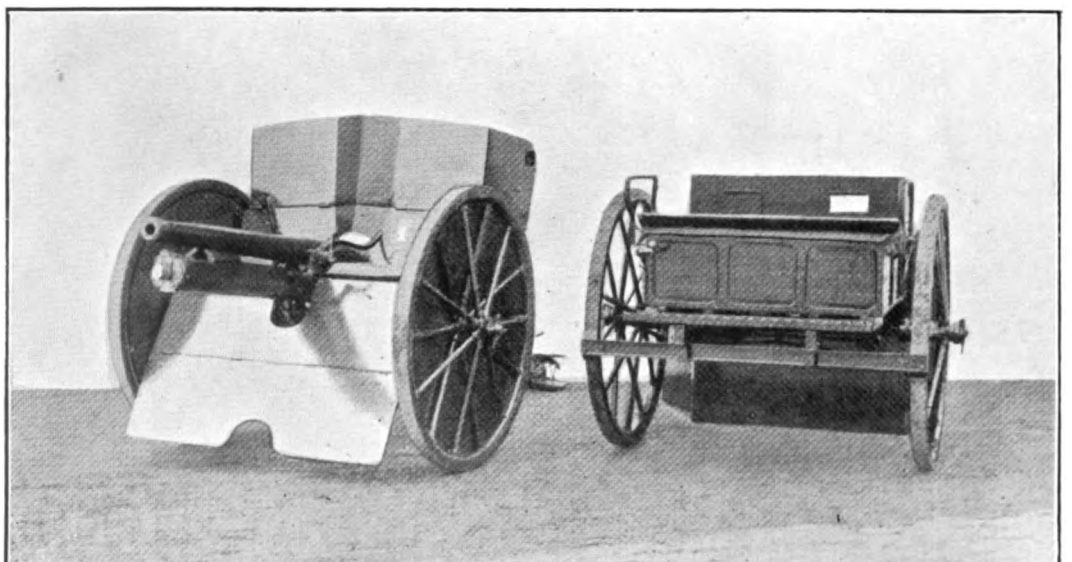

FULLY-SHIELDED GUN AND WAGON.

EHRHARDT.

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Thus if the wavy line be two feet long, it shows that the gun has recoiled through that distance. If the tuning-fork used vibrates 500 times per second, and 50 waves are counted on the smoked surface, then the gun took one-tenth of a second to recoil; if ten waves are counted on the first six inches of the line, then the recoil-velocity over the first six inches was 25 feet per second.

The Buffer-gauge.

The hydraulic buffer of a long-recoil gun is designed to produce a perfectly regulated resistance throughout the recoil. For the pupose of adjusting the pressure in the buffer, which constitutes the resistance to recoil, the buffer-gauge is used.

This consists in principle of a pressure-gauge in which an indicator is forced upwards against a spring. A special hollow piston-rod is inserted in the buffer and the gauge screwed on to the outer end of it. A long strip of smoked sheet metal is attached to the gun, so that as the gun recoils the indicator traces a line upon it. If the pressure is uniform during recoil, the indicator remains at the same height, and traces a straight horizontal line; if the pressure is irregular the indicator goes up and down, producing a wavy line. If this is found to be the case the buffer must be regulated by altering the windage between buffer and piston at different points till the indicator traces a curve corresponding to the graduated pressure required. This, in practice, is effected by altering the depth of the channels or grooves in the inner walls of the buffer (called *ports*) through which the liquid flows past the piston.

A difference of $\frac{1}{100}$ inch in the depth of the ports is found to produce a marked difference in the steadiness of the gun.

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CHAPTER II.

THEORY OF CONSTRUCTION OF GUNS.

STEEL.

Steel is the only material now used in gun-making.* There are many different kinds of steel, ranging from *high* steel (that is, containing a high percentage of carbon) of which razors are made, down to the mild steel used for boiler-plates. High steel is harder, stronger, and more elastic than mild steel, but it is also more brittle. When steel gun were first made only the softest and toughest of mild steel was used, principally because it was then impossible to obtain large ingots of high steel of good quality. With improvements in steel we are now getting to use much higher steel than before. A few years ago the steel used at Woolwich was specified as 30 tons tenacity; that is, that a bar of steel an inch square would stand a pull of 30 tons before breaking. In 1902, the Bethlehem gun-factory (U.S.A.) was using steel of 60 tons tenacity, and Creusôt (France) was using 50 ton steel. The Bethlehem steel is steel to stretch 16 per cent before breaking.

Hardening. Both high and low steel are improved by hardening and tempering. Hardening consists in heating to a red heat and quenching in oil or water; tempering consists in re-heating to modify the effect of the hardening. Mild steel does not harden to anything like the same extent as high steel, but it gains in strength and elasticity thereby.

Nickel Steel. The addition of nickel to the steel makes it tougher without loss of strength. The steel used in the 15-pr. Q.F. gun contains 6 per cent of nickel, and has a breaking strain of 51 tons to the square inch.

Vanadium Steel. The addition of vanadium to steel, in the proportion of 3 parts per 1000, is found to produce a great increase of strength and hardness. It is believed that the vanadium has the effect of reducing all oxides that may be present in the casting, and so rendering the steel perfectly homogeneous. Vanadium steel is too expensive to use in large masses. But we shall probably see it introduced, in the near future, for gun-shields and for small portions of lock mechanism.

* Except in Austria, where, for reasons connected with economy and local facilities of manufacture, hard-drawn bronze is still used. This, however, involves a material increase of weight.

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Chrome Steel is an old invention. In the form of nickel-chrome steel it is now used by some of the largest firms, such as Schneider of Creusôt, as gun-steel. It is difficult to manufacture, since minute variations in the percentage of chromium make a marked difference in the quality of the steel.

Tungsten or Wolfram steel is hard and heavy. It is well suited for armour-piercing shrapnel bullets; but the quantity of wolfram commercially available is insufficient to admit of the manufacture of such bullets on the scale required for military purposes. Messrs. Ehrhardt are said to use nickel-wolfram steel for their gun-shields.

Molybdenum Steel is said to make good springs. It is very expensive.

Krupp's Spring Steel attracted much attention in the engineering world in 1904. According to official tests, this steel, in the form of flat wire gun-springs, has a tenacity of 137 tons to the square inch with an elastic limit of 89 tons. These figures are very remarkable, and, up to 1905, nothing approaching these results had been obtained in England or America.

Ehrhardt's and Cammell's Spring Steel. The Krupp record has now (1906) been broken. Messrs. Ehrhardt produce spring steel with a tenacity of 142 tons (treated), and elastic limit of 120 tons, with 3 per cent of elongation. In England, Messrs. Cammell Laird produce spring steel of tenacity 123 tons, elastic limit 107 tons, and elongation before breaking of 2 per cent. The latter steel is believed to contain molybdenum.

METHODS OF CONSTRUCTION.

The first steel guns, made by Krupp, were bored from solid blocks of steel. Such guns, however, contain a large amount of useless metal, for the following reason:

Steel is elastic like india-rubber, though not to the same extent. If a flat india-rubber ring be stretched to breaking, it will give way at the inside edge; similarly if a ring of steel be strained to bursting it will begin to tear from the inside.

For instance, take a thin section of a gun, forming a flat circular ring say one foot in internal diameter and one foot thick. Then, neglecting decimals, the circumference of the inner layer is 3 feet, that of the outer 9 feet. Now suppose the ring stretched till its external diameter is doubled, making the outer circumference 18 feet. Since an elastic body—whether metal, india-rubber, or anything else—does not increase in size when stretched but merely alters its form, then the thickness of the ring, when its circumference is doubled, will be only half what it was before. That is, the ring will be now only six inches thick, its internal diameter five feet, and its internal circumference 15 feet. Then the outer layers will have been stretched from 9 to 18 feet, the inner from 3 to 15 feet, or as 1 to 2 and 1 to 5 respectively.

On investigating the problem in the orthodox manner, with the aid of the Integral Calculus, it will be found that the above superficial

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demonstration is pretty wide of the truth, the real proportions being as 1 to 4, not 2 to 5. But at any rate it serves to show that the inner layers of metal in a gun are exposed to a far more severe strain than the outer ones.

BARLOW'S LAW.

It has been calculated mathematically that the strain on the metal of the gun decreases as the square of the distance from the centre. That is, if we take an 8 inch gun at a point where the metal is four inches thick, then the outside of the gun will be twice as far from the centre as the inside; but the strain at the surface of the bore will be *four* times as great as on the outside.

Barlow and Constant. This law of squares is known after the inventor, as "Barlow." It is found, however, to be not quite accurate, and a correction or modifying factor, which is a constant for any particular size of gun, has to be introduced.

This formula is known as "Barlow and Constant" and is the basis of the construction of all modern guns. If, for instance, the Government were to order a new 20 pounder, its dimensions would be calculated in the Royal Gun Factory by this rule.

Built-up Guns.—It follows from Barlow's law that if a gun be made from a single block of steel, a great portion of the metal will be nearly useless dead weight, since the outside of the block will not be strained to anything like it full strength.

To avoid this the method of building up guns of successive layers of steel was introduced. Each layer is shrunk on to those inside it, compressing the inner layers and strengthening them at its own expense, and so the strains on a gun are nearly equalized throughout.

Thus, if a gun be of such a thickness that the strain in the bore on firing is 20 tons per square inch, and that on the outside only 10 tons, then if the gun be made of two thicknesses, the outer being shrunk on so that it is in tension to the amount of 5 tons per square inch, compressing the inner one to the same amount, the strain per square inch on firing will be 20 tons—5 tons on the inner layer and 10 tons + 5 tons on the outer.

The strain *in each layer* will still remain unequal, the metal on the inside of each doing more than its share of the work. To obviate this large guns were made in a number of different layers shrunk on one over the other, so as to get the strain as nearly as possible uniform throughout. The 12 inch of 25 tons, for instance, had six superposed layers.

Wire Guns.

In recent years this system has been superseded by the method invented by Mr. Longridge, of winding guns with wire. Each successive layer of wire (or rather steel ribbon) is wound on at an increasing tension, so that on firing all the layers are equally strained.

A wire gun consists essentially of a steel tube (called the A tube,) a number of layers of steel ribbon, and an outer steel jacket. The jacket serves principally to stiffen the gun.

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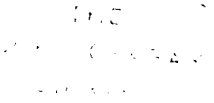

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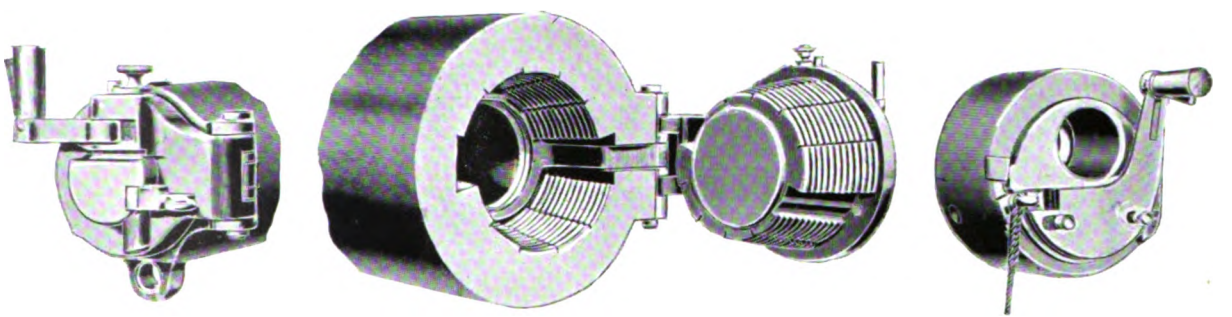

Q. F. BREECH ACTIONS.

KRUPP.

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Besides the better distribution of strain, another advantage of the wire-winding system consists in the greater strength of the metal. Steel wire has been made strong enough to stand a strain of 150 tons to the square inch. This is exceptional, but the ordinary steel wire used at Woolwich is tested to 100 tons to the square inch, which is twice the strength of gun steel.

The wire-winding system is now applied to all guns from the 13pr. R.H.A. gun to the 12 inch.

With very long wire-wound guns of large calibre the difficulty of providing sufficient rigidity becomes serious, as the wire only affords circumferential support. But this does not apply to field guns.

Ehrhardt System.

The 15pr. Q.F. gun is an exception. It consists of an inner tube and a jacket, each formed by forcing a mandril into an ingot of red-hot steel. This method compresses the inner layers of metal, and so, to some extent, serves the purpose of the more expensive wire-winding system. It is however only applicable to small guns.

Longitudinal Strength.

This is a matter of minor importance, since the longitudinal strain, tending to pull the gun asunder, is much less than the radial strain tending to burst it.

Thus in a 6 inch gun with a pressure of 18 tons per square inch in the powder-chamber, the pressure acting on the base of the shell and the front of the breech block is roughly $6 \times 6 \times \frac{3}{4} \times 18$ tons, or 243 tons. If the A tube be only two inches thick, its cross section will be (very roughly) $6 \times 3 \times 2$ square inches, or 36 square inches; if the strength of the steel be 40 tons per square inch, this gives a longitudinal strength of 40×36 or 1440 tons, so that there is a considerable margin of safety.

BREECH ACTIONS.

Three principal methods of closing the breech are in use in England and on the Continent, namely:—

Interrupted screw.
Wedge.
Eccentric screw.

Interrupted Screw.

If we take a screw fitting into a nut, and cut away the threads of the screw all down the right side, and the threads of the nut all down the left side, then the screw may be pushed straight into the nut. And if the screw now be given half a turn, the remaining threads will engage with the remaining threads of the nut, and the screw will be firmly held.

This would be a lop-sided arrangement, so in practice the breech screw is cut away for every alternate quarter of the circumference, and the nut—that is, the screwed breech of the gun—is cut away to match. Only one quarter of a turn is then required to lock the screw.

The breech screw is supported by a frame called the carrier, pivoted to the breech of the gun at one side.

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Conical Breech-screw.

If the breech-screw be cylindrical, then, unless the arrangement described in the next paragraph is adopted, after turning it to disengage it, it must be pulled straight out before it can be swung round on the carrier clear of the breech. But if it be made conical, it can be swung clear as soon as it is turned round. The only condition is that the surface of the cone must fall within a circle described from the hinge-pin of the carrier. This is known as a single-motion breech action. It is applied to guns with which metallic cartridge-cases are used.

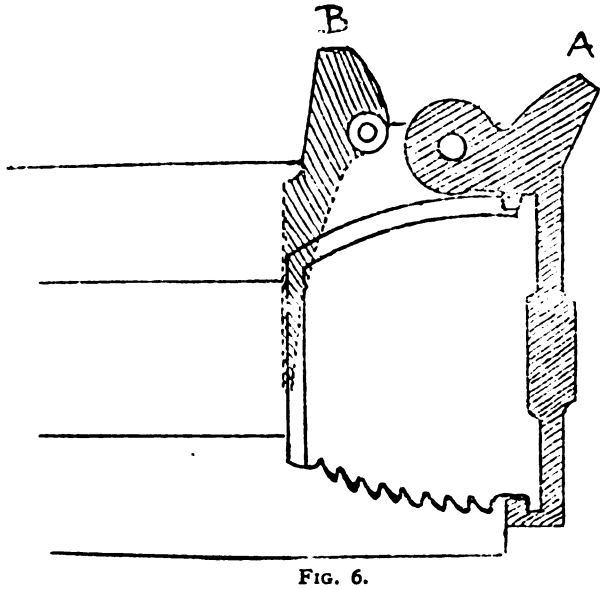

FIG. 6.

Fig. 6 gives a top view of the curved conical, or rather ogival, breech-screw used in the 15pr. Q.F. gun, the rotating gear and firing gear being omitted. The carrier and the extractor are shaded. It will be noted that on throwing open the breech the projection A on the carrier strikes the tail, B, of the extractor, causing it to forcibly eject the empty cartridge-case.

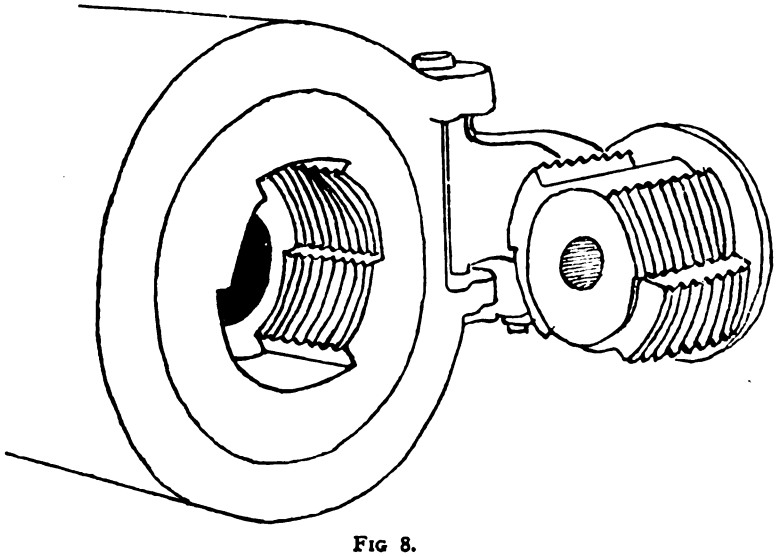

FIG 8.

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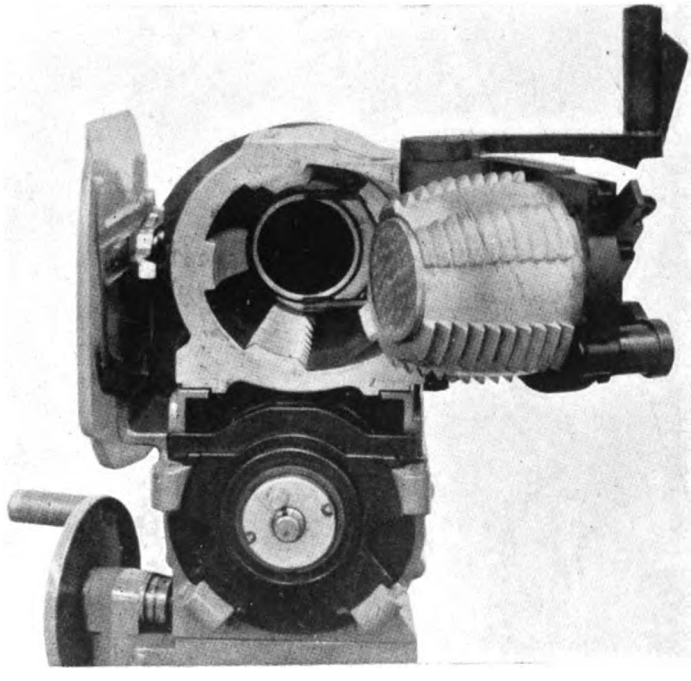

SINGLE-MOTION OGIVAL BREECH SCREW.

EHRHARDT.

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Welin Screw.

This differs from the ordinary pattern in that the screw is stepped, giving an increased bearing surface. It will be observed that in Fig. 8, which represents a cylindrical Welin screw, only two of the six segments are plain, the others being threaded.

THE SINGLE-MOTION CYLINDRICAL BREECH-SCREW.

If the projecting screw threads are cut away at top and bottom to the form shown in the sketch, and if the hinge of the carrier is placed at some distance to one side, as at A A, then it is found possible to make a cylindrical breech-block which can be swung straight out without first withdrawing it by a straight pull. This is done by deepening the recess in the breech-piece at B so as to clear the corner of the block as it swings. By this method it is even found possible to produce a breech-screw coned in the reverse direction—that is, with the threaded portion of larger diameter at the fore end of the breech-screw than at the rear end. This form gives a great increase of strength, and is used in the 18pr. and 13pr. Q.F. equipments.

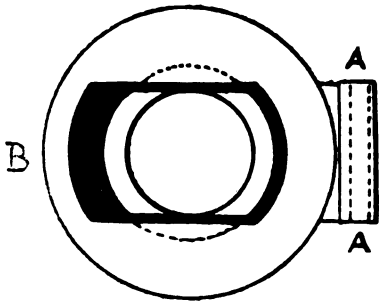

FIG. 9

This action is more compact than the conical screw, and its only disadvantage is the extra metal required to strengthen the breech-piece to make up for the recess at B. It is used in our own new field equipment and in the American gun.

The Wedge.

A wedge of slight taper slides in a slot across the breech. There is a hole in the thinner end of the wedge, or rather, the thin end of the wedge is cut away semi-circularly, so that when it is pulled out the hole corresponds with the bore, and the shell and cartridge can be inserted. When the wedge is pushed home, the solid part of the wedge comes opposite the bore, and so closes the breech. This action is still a favourite in Germany. Its merits are strength and simplicity. A good example is the Krupp wedge seen in Fig. 17B and the Ehrhardt wedge in Figs. 10 and 10B. Note how the left of the breech is cut away to facilitate loading. The plate seen to the left of the breech is a guard to prevent the layer from getting his arm in the way of the recoiling gun.

The Eccentric Screw.

Suppose the breech-screw made larger than the gun, and having a hole bored down it at one side of the centre. Then if the screw be given half a turn, the hole will coincide with the bore; if it be turned back again, as in the figure, the solid part of the screw will come opposite the bore and so close the breech.

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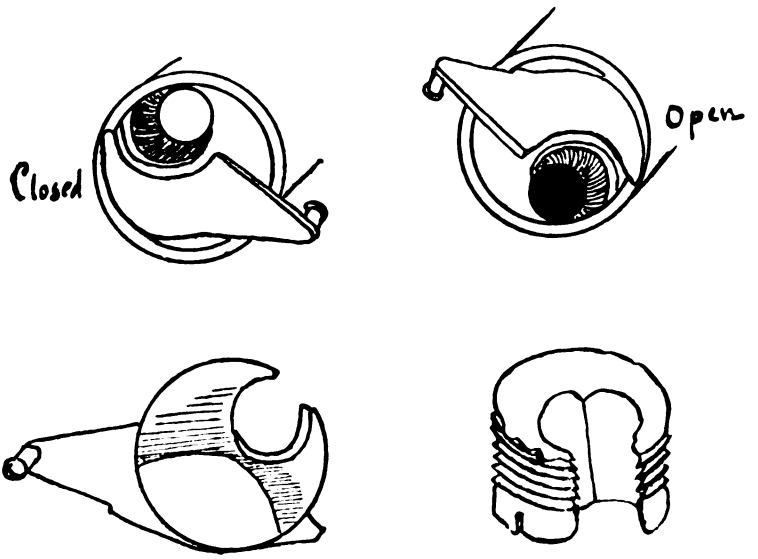

FIG. 11.

The eccentric screw is, in fact, a circular wedge.

This action is quick to manipulate, and, being all enclosed, is not liable to damage. It is therefore used in some Q.F. field guns, as in the French and Norwegian guns, and in the Elswick 1904 13-pounder. It is too heavy for large guns.

Falling Block.

In small natures of Q.F. guns, as in the Hotchkiss and Nordenfelt, the falling block is used. This is simply a wedge without any taper used vertically.

Obturation.

In all modern guns up to the 6 inch the escape of gas through the breech-loading gear is prevented by enclosing the powder in a solid-drawn metal cartridge case. This expands against the sides of the bore on firing and so seals the breech.

For heavy guns the weight of the cartridge-case becomes excessive and an obturator is used. In England this consists of a pad of asbestos and grease fixed to the front of the breech-screw and covered by a mushroom head.

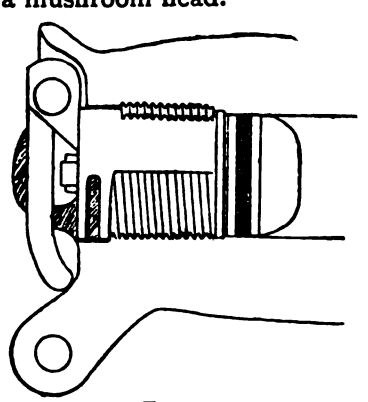

FIG. 12.

On discharge the soft pad is compressed and swells out so tightly against the surface of the bore as to prevent any gas from escaping past it. This system only works well with the cylindrical breech-screw, which is therefore used in all our heavy guns. With the wedge action, when intended for a bare charge, a soft copper ring is used on the solid part of the wedge, which is pressed tightly against the breech when the wedge is driven home.

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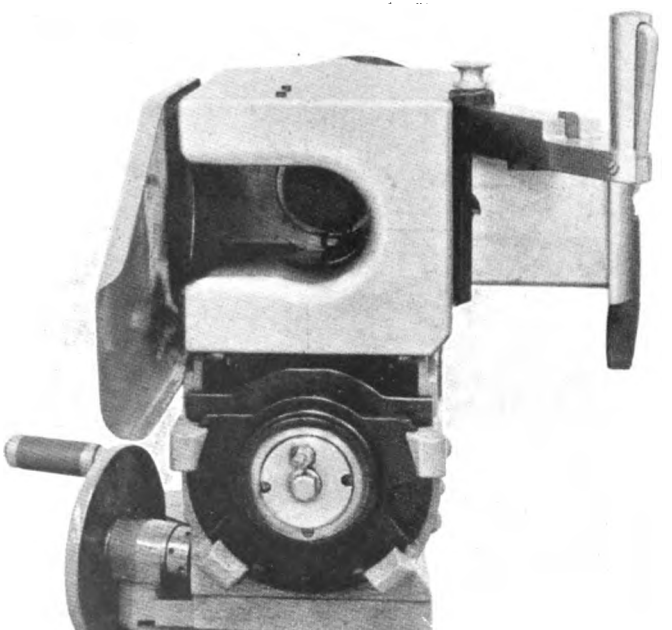
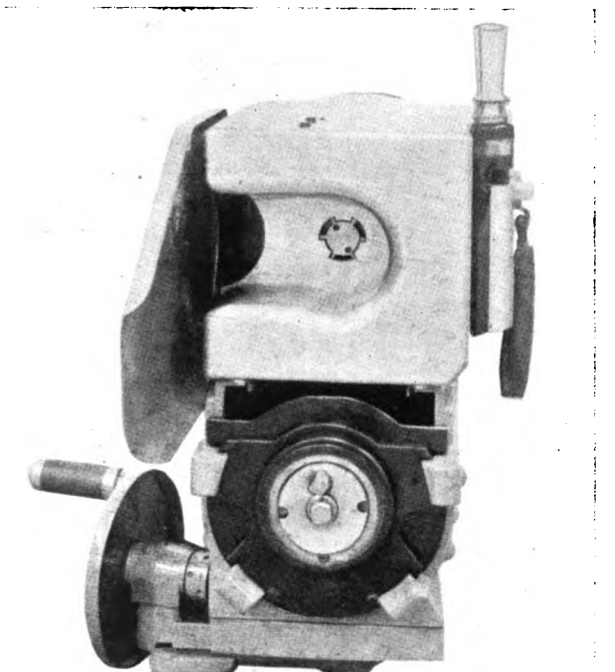


WEDGE BREECH ACTION, OPEN.

EHRHARDT.



WEDGE BREECH ACTION, CLOSED.

EHRHARDT.

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AUTOMATIC SAFETY DEVICES.

All modern breech-actions have safety devices which prevent the gun from being fired till the breech is closed and locked.

The "safety" most commonly used is a bolt which locks the striker, and is not released till the end of the motion which locks the breech-block.

The swinging block fitted to the new American field gun has a novel safety device. The block is not set quite in line with the axis of the gun, but ¼ inch to one side. The striker is not in the centre of the block, but so as to be in line with the axis of the gun when the block has been rotated in the motion of locking. The effect of this double eccentricity is that when the breech is being closed the striker is not opposite to the cap in the cartridge, so that if the striker happens to stick or protrude no harm is done. The striker does not come opposite to the cap till the block has been revolved through a quarter of a circle to lock it.

This action is known as the *eccentric block*, and must not be confounded with the *eccentric screw* described above.

RELATIVE MERITS OF DIFFERENT BREECH ACTIONS.

The strongest and simplest action is the wedge, which also lends itself to simple and efficient percussion firing gear. Next in order of simplicity comes the eccentric screw, which is however considerably heavier than the wedge. The swinging block, when made as a single-motion action, is far more complicated than either of the above. It has however two advantages which more than make up for its defects.

In the first place, it serves as a rammer to drive the cartridge home. Instead of the gunner having to push the cartridge right home into the breech—which is sometimes no easy matter when the chamber is foul—he has only to launch it in, when the swinging block, as it closes, completes the loading.

In the second place, the swinging block gives a far more powerful extractor than either of the other actions. With the eccentric screw the extractor is worked by a cam groove, with the wedge by a tripper on the front face of the wedge. But with the swinging block the "tail" of the extractor is made to project outside the gun, so that the block at the end of its backward swing strikes it like a hammer and forcibly ejects the cartridge case.

The provision of an efficient extractor is a matter of great importance, since in war-time numbers of hastily-manufactured cartridge cases would have to be used, which might not all be true to gauge, It is therefore desirable to have a powerful action capable of dealing with inferior ammunition without liability to jam.

FIRING GEAR.

All Q.F. field guns have percussion locks. These are usually "trip-locks" which do not require to be cocked; the pull of the firing lever first draws back the striker, compressing the mainspring, and then releases it. This action can be repeated in case of a miss-fire. There is some difference of opinion as to whether the layer or the elevating number should fire, but the former arrangement would appear to be best, since the layer is likely to lay more steadily if he knows that the gun cannot go off till he is ready for it.

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CHAPTER III.

SIGHTS.

The theory of the action of sights is simple enough, especially when applied to the arc sight which has superseded the old tangent scale.

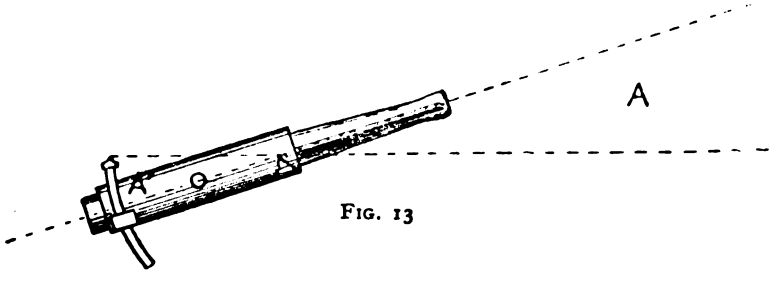

FIG. 13

Thus, in the figure, the elevation A above the target, which is given to the gun in order to enable the shell to reach the target, is equal to the angle A′ measured on the arc sight. In this instance the line of sight, when the back sight is down, is on a level with the axis of the piece; but if any other position for the sights is more convenient, these may be set higher or lower, further to the front or further to the rear, if only the line of sight with back sight at zero is *parallel* to the axis of the piece. It is, in fact, usual to set the sights as high as conveniently possible in order that the line of sight may clear intervening cover high enough to partially conceal the gun.

Deflection.

Suppose that the shot, owing to the wind or other causes, has fallen to the left of the target, then the gun must be pointed to the right of the target in order to shift the point of impact to the right. Then, if the gun be looked down upon from above, as in the figure,

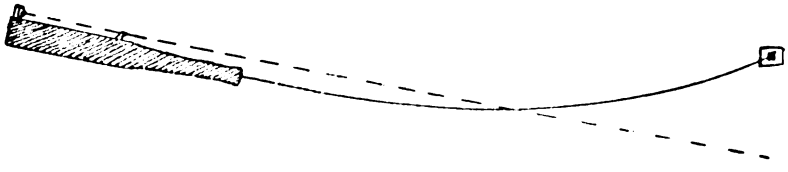

FIG. 14.

the line of sight, with the deflection leaf in the middle, will pass to the right of the target. To bring the line of sight on to the target we have to shift the moveable leaf, with the notch in it, over to the right. This is called "giving right deflection."

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The amount of deflection is arrived at by estimating the lateral distance to the left of the target at which the shot fell and expressing this in degrees and minutes. To do this we use the gunner's formula, which is nearly correct for small angles, that "a minute is equal to an inch at 100 yards;" that is, that one yard of error requires 36 minutes to correct it at 100 yards, or 3.6 minutes at 1000 yards. This is expressed in the rule "Reduce the error to inches and divide by the number of hundreds of yards in the range."

Deflection for Drift.

We know that the effect of the rotation of the shell is to make it deviate more and more to the right of its original direction as it flies down the range. The greater the range, therefore, the more we must aim to the left of the target to make a hit; that is, the more left deflection we must put on.

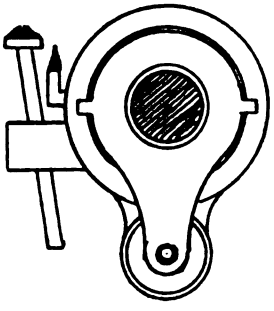

FIG. 15.

This is conveniently effected by setting the back sight at an angle in the gun, so that when right down it gives no deflection, but the higher it is raised the greater the distance of the notch to the left of the original line of sight.

Since the amount of drift is not in proportion to the range, but is proportionately greater at long ranges than short ones, this method of correcting for drift by inclining a straight back sight is not accurate. At most we can only give an *average correction* in this way, which is too great at short ranges and too small at long ones. If the back sight could be curved sideways a closer approximation might be attained, but for a field-gun this refinement would not be worth the additional complication.

In Scott's telescopic sight (of which more hereafter) the above correction is not considered sufficiently accurate, and a table of drift for each elevation is given.

In our own Q.F. equipments an average correction for drift is given by raising the right trunnion of the cradle above the left. Take an extreme case and suppose the right trunnion six inches higher than the left and the gun elevated from zero to 45 degrees; then it will be plain, on consideration, that the more the gun is elevated the more it will point to the left of its original line.

Difference of Level of Wheels.

Suppose the back sight raised one foot and the gun on sloping ground so that the right wheel is much higher than the left. Then the effect of the difference of level will be to tilt the sight over to the left, so that the notch is considerably to the left of its position when the back sight is down. We shall unconsciously, in fact, be giving left deflection and the shell will pitch to the left of the target. To correct this it is necessary to give right deflection. The gunner's rule for this, which is sufficiently accurate for practical purposes, is:

> "Multiply the number of inches difference of level of wheels by the number of degrees of elevation, and give that number of minutes of deflection towards the higher wheel."

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Instead of taking the number of inches of difference of level we may set the clinometer crosswise on the breech and measure the inclination in degrees. This, multiplied by the degrees of elevation, will give the required deflection.

By taking an extreme case it will be seen that the shell will tend to go to the side of the lower wheel; for if the back sight be raised to 10 degrees and the gun turned over on its side with the right wheel on top, then the gun, if previously laid on the target, will now be pointing 10 degrees to the left of it.

In some B.L. Mountain Battery equipments, intended to be used on rough ground, this error was obviated by setting the straight tangent scale in a socket pivoted parallel to the axis of the piece, and putting a heavy knob of metal on the end of it, so that, seen from behind, it always hung straight up and down.

Theory of Scott's Sight.

Col. Scott's telescopic sight has for many years done good service in the Horse and Field. Now, however, that the sights are attached to the non-recoiling portions of the carriage, we are able to fix the telescope directly to the arc sight or rocking bar, and a separate telescopic sight is not required. The constructional principles involved are however of interest, since it is upon these principles that the design of the modern goniometric sight is based.

Scott's Sight consists of a telescope mounted in a steel frame. This frame has longitudinal trunnions fitting into Vs on the gun. These Vs are so arranged that the axis of the trunnions of the sight-frame is exactly parallel to the axis of the gun. By means of a cross level the frame can be so adjusted that the cross axis on which the telescope is mounted is truly horizontal.

This at once eliminates any error due to the sights being tilted owing to difference of level of wheels, since once the sight-frame is levelled the telescope moves up and down in a vertical plane. It also eliminates any error due to one trunnion of the gun being higher than the other; for, suppose the sight set and levelled, and the gun elevated till the telescope points at the target, and then suppose the sight immoveably suspended in the air in that position; then, since the axis of the gun must always remain parallel to the longitudinal axis of the sight frame, the gun and carriage might be revolved about the trunnions of the sight-frame without altering the quadrant elevation of its axis.

MODERN Q.F. SIGHTS.

The improvements in the accuracy and rate of fire of modern field-guns have led to the introduction of more perfect sights. In all of these the object of the improvements is to facilitate the layer's work, so as to make laying easier, more accurate, and above all, quicker.

Six principal sights are in use.

1. The original Korrodi, commonly known as the "Arc Sight."

This is the sight fitted to our 15 pr. Q.F. guns (Fig. 16).

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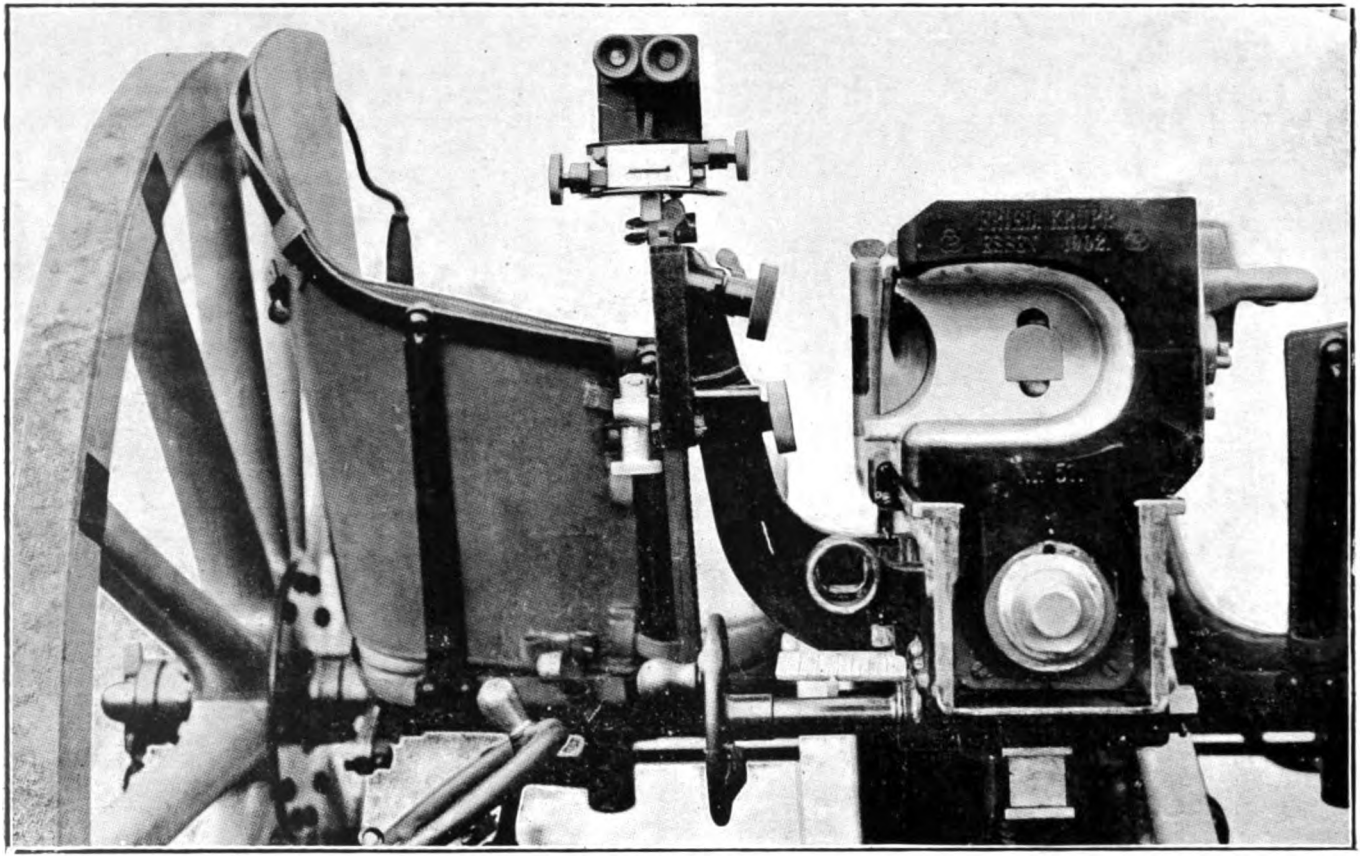

KRUPP ARC SIGHT, WITH TELESCOPE AND FINDER.

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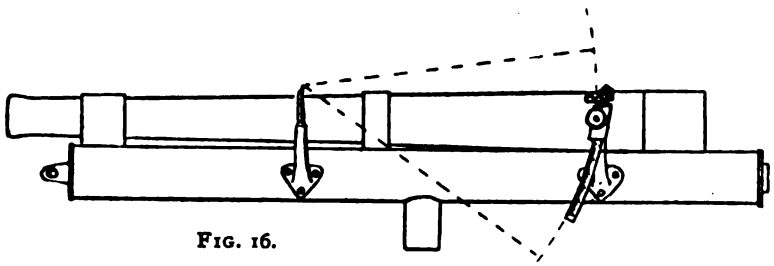


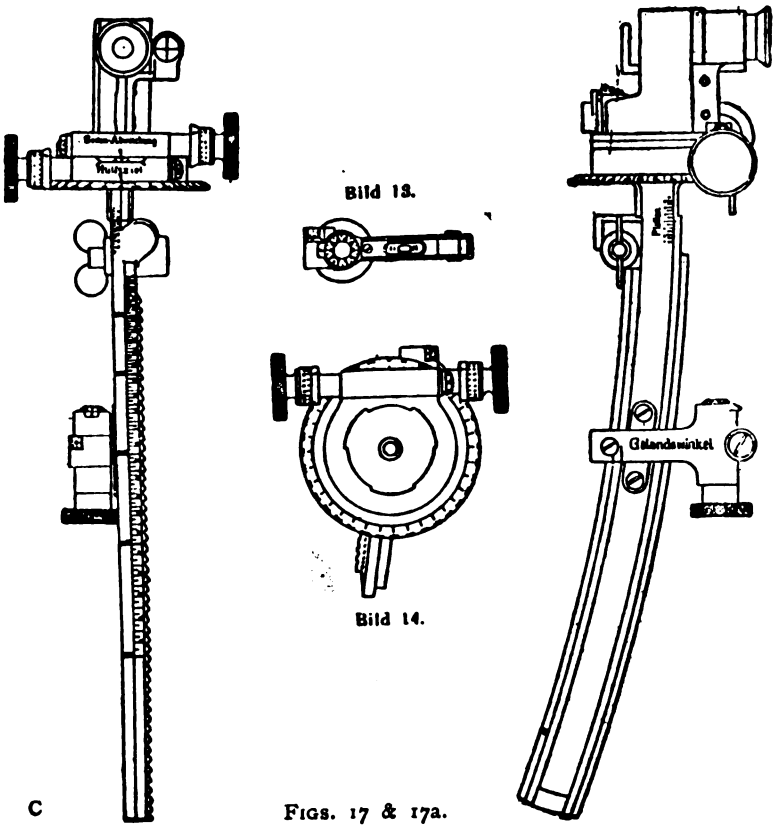
FIG. 16.

It is attached to the cradle and consists of a steel arc, forming a portion of a circle described from the point of the foresight as centre. This arc carries a spirit-level in addition to the deflection leaf and notch, and is moved up and down in its socket by turning a drum upon which the range-figures are marked in a spiral. On raising or lowering the arc, the inclination given to the spirit-level is equal to the number of degrees through which the arc is moved, so that the arrangement forms an open sight and clinometer in one.

If desired, a telescope can be fitted to the top of the arc, converting it into a telescopic sight. In this case a prismatic telescope is used, similar to one barrel of a Zeiss field glass fitted with cross wires or pointer.

This form of sight is still used by Messrs. Krupp and Ehrhardt in their new guns; it is also used in the Italian equipment.

2. The Krupp Arc Sight.



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FIGS. 17 & 17a.

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One form of this is illustrated in the annexed figures. It has a prismatic telescope, similar to one barrel of a Zeiss field-glass, mounted on top of the arc upon a circular graduated base-plate which enables it to be turned in any direction for laying on an auxiliary mark. The arc is double, the inner arc moving within the outer to correct the fuze, so that the setting of the fuze always corresponds to the gun range.

The second eyepiece seen in the rear view is a "finder" placed alongside the telescope. Note the inclined non-slipping pinion for elevating the sight, also the traversing wheel and scale below the sight-bracket.

3. *The Rocking Bar Sight.*

A convenient means of constructing a telescopic sight is to connect the foresight and the backsight by a straight bar upon which the telescope is fixed. A further step in advance is to attach the foresight and the backsight notch to the bar and mount the bar on a horizontal pivot near the centre. This constitutes a "rocking bar."

These sights are convenient to use with a shielded field-gun where the space behind the shield is limited.

An excellent form of rocking bar is made by Messrs. Ehrhardt, and is shown in attached sketch (Fig. 18). The bar is pivoted upon the

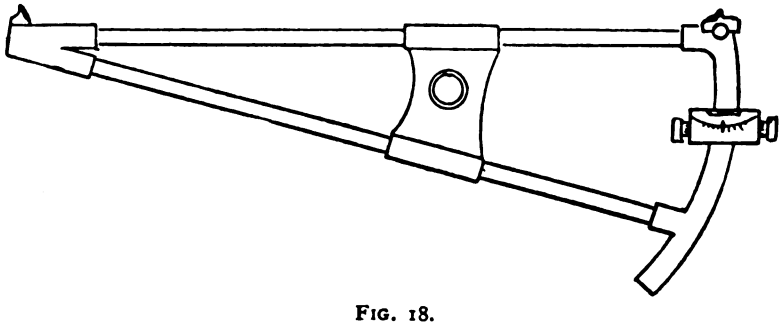

FIG. 18.

trunnion of the cradle (which does not recoil) and is elevated and depressed by a worm wheel or pinion engaging with its curved base.

Besides the horizontal pivot about which the bar turns for elevation, there is also a vertical pivot allowing the whole gear to swing right and left for deflection.

When used with a telescope, the rocking bar has the advantage of dispensing with the small screw-gear and minute graduations used with a telescopic sight of the old pattern, and thus forms a serviceable and accurate military machine.

4. *The Goniometric Sight.*

Now that fire from behind cover is the normal method, it is necessary to have a sight which enables the gun to be layed for direction on an aiming point in flank or in rear.

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Page 18.—The goniometric sight is now styled in our Service the "dial sight."

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The distinctive feature of the goniometric sight is the circular graduated base-plate, on which a short telescope or sighted ruler is pivoted so that it can be turned in any direction. Besides the main graduations on the base-plate there is a separate deflection scale on which corrections of line for each individual gun can be set.

The base-plate can be mounted on an arc sight as in Fig. 17, or on a separate pedestal as in the German Q.F. gun. (See Part IV.)

A better method is to mount it on the reciprocating principle, which is that governing the construction of Scott's sight. The base-plate is attached to a pedestal on the cradle by a hinge accurately parallel to the axis of the gun; above this there is a second hinge at right angles to the first. Then whatever be the difference of level of the wheels, the vertical plane passing through the zero line of the scale is always parallel to that passing through the axis of the gun. And when the base-plate is levelled the telescope or sight-vanes will enable us to measure the true horizontal angle between the line of departure and the aiming-point.

And since the levelled base-plate affords a true horizontal plane from which to measure the quadrant angle of the gun, then if to the transverse hinge we apply a device for measuring angles, such as a spirally-graduated drum or a tangent screw, we have a means of laying the gun also for quadrant elevation.

5. The Pedestal Sight.

This is a special form of the goniometric sight, and is used only with the "independent line of sight" described below.

It consists of a standard or pedestal attached to the "intermediate carriage," and supporting a telescope fixed at right angles to it. This telescope is mounted on a graduated circular table on top of the pedestal, and can be traversed horizontally through a complete circle. The sight can thus be used either for aiming directly at the target or for aiming at an auxiliary mark to right, left or behind the gun. When used for direct laying the telescope remains fixed at right angles to the pedestal, the inclination due to the angle of sight being given by elevating or depressing the intermediate carriage to which the pedestal is attached; when the sight is directed at an aiming point to a flank, the telescope itself is elevated or depressed by a tangent screw. In the latter case the gun elevation is given by clinometer.

One advantage of this sight is that by lengthening the pedestal it can be used for direct fire by a layer standing erect, or even standing on the limber, while the gun is kept back behind the crest of a hill so as to be concealed from view. (Fig. 19.)

In the French pedestal sight no telescope is used, but the sight is directed on to the target by using the *collimateur*. This instrument is the same as the "ghost" sight described below, except that the front plate is silvered to form a reflector. A vertical and a horizontal strip of the silver coating, each 2 millimeters in diameter, are cut away, so as to leave a cross of clear glass as in Fig. 20.

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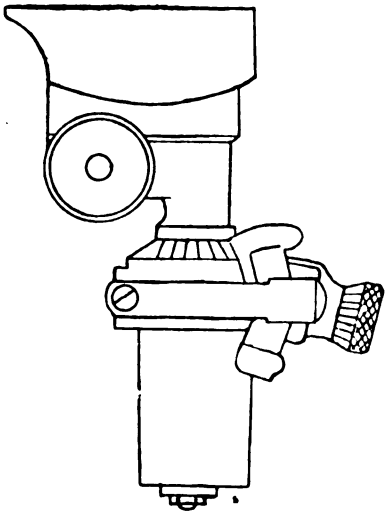


FRENCH PEDESTAL SIGHT.
FIG. 19.

The layer at first keeps his eye about a foot behind the eye-piece, looks alternately at the object and the cross, and works his elevating and traversing wheels till he brings first the horizontal line and then the vertical line to coincide with the object. He gives the final adjustment by bringing his eye close to the instrument and looking through the cross at the object.

The collimateur is rarely used for laying for elevation. As a rule the gun is layed for elevation by clinometer, and for line by a conspicuous auxiliary mark. The relative direction of the mark is measured by the battery commander with a telescope mounted on a graduated stand.

The necessarily small scale of the pedestal sight entails small graduations leading to errors in setting.

The pedestal sight as applied to howitzers is described in Chapter X.

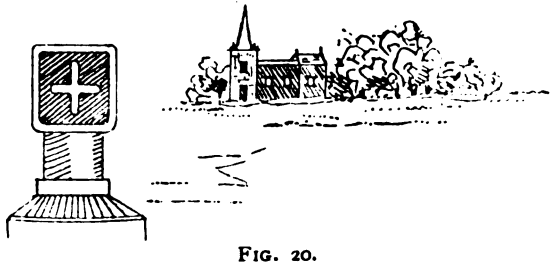
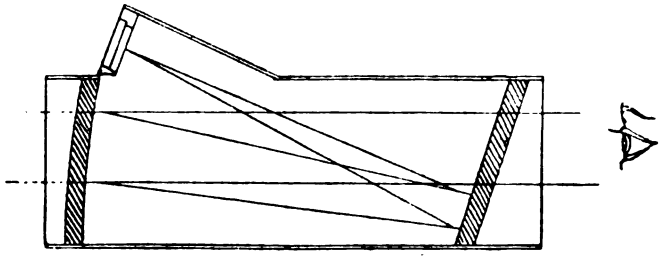


FIG. 20.

6. The Ghost Sight. (Fig. 21.)

Suppose a square box as in the diagram, closed in front and rear by glass plates. The lower half of the rear glass plate is silvered inside. An inclined tube is fixed into the top of the box; it is closed at the upper end by a ground glass plate with a cross cut upon it. A lens in the tube (not shown) throws the image of the cross upon the mirror surface of the rear glass plate, whence it is reflected to the



THE GHOST SIGHT.
FIG. 21.

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front glass plate and thence back to the eye. The front glass plate is covered with a barely perceptible layer of some semi-transparent material, such as galena, which ensures the reflection of the image of the cross, while it allows the light from the target to pass in. The effect is that the layer sees the landscape before him with the image or ghost of a cross in the centre of the field. Since the cross appears to be at the same distance as the target, it is an easy matter for the layer to make cross and target coincide by working the hand-wheels.

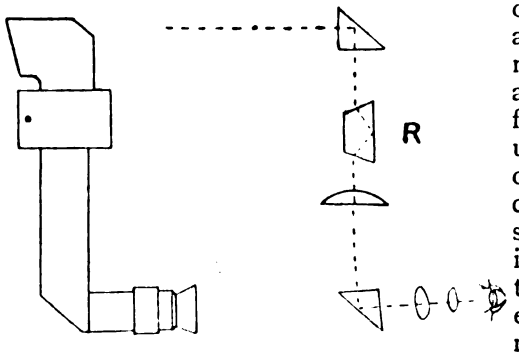
From its compactness the ghost sight is well adapted to use as a pedestal sight. But it absorbs a good deal of light and is liable to derangement from dust getting on the mirror surfaces. It is usually fitted with a telescopic eye-piece.

To avoid the possibility of dust getting on the reflecting surfaces, the ghost sight is sometimes made of a single block of clear glass. This, however, absorbs more light than is desirable.

7. The Goerz Panorama Sight.

Supposing it were possible to point the object-glass of a telescope in any direction without moving the eye-piece, this would afford a view in any desired direction without traversing the gun. (Fig. 22.)

This is effected by the Panorama Sight. It consists of a short telescope bent at right angles and surmounted by a moveable head. The head is fixed on a horizontal graduated table and is capable of being turned in any direction by a tangent screw. The object-glass is in the vertical tube and the light is reflected to the eye by two prisms or mirrors inclined at 45°, one in the moveable head and one at the angle of the telescope.



GOERZ PANORAMA SIGHT.
FIG. 22.

These two prisms would not suffice to give an erect image, as if the head were turned round the image would appear more and more inclined until at 180° it would appear inverted. A rectifying prism "R" as shewn in the second figure is therefore introduced. This is connected by gearing with the moveable head so as to revolve with it, but at only half the rate of angular revolution. This gives an erect image in whatever direction the head is turned.

The magnifying power is 4, the field 10°.

The sight may be mounted either on an arc, a rocking bar, or a pedestal. It serves both as an ordinary telescopic sight and as a goniometric sight for laying at an auxiliary mark. It has the advantage of requiring only a small hole in the gun-shield and of giving a high line of sight, enabling the gun to be kept well back under cover. It is liable to the objection common to all prismatic optical appliances, that it is easily put out of action by dust on the faces of the prisms.

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THE INDEPENDENT LINE OF SIGHT.

This device for quick and easy laying was first brought out by the French in their Q.F. field equipment. It is now used by the leading French and English makers, but has not found favour in Germany for field guns, although both Krupp and Ehrhardt have brought out sights of this type.

The theory of the invention is as follows:—(Fig. 23.)

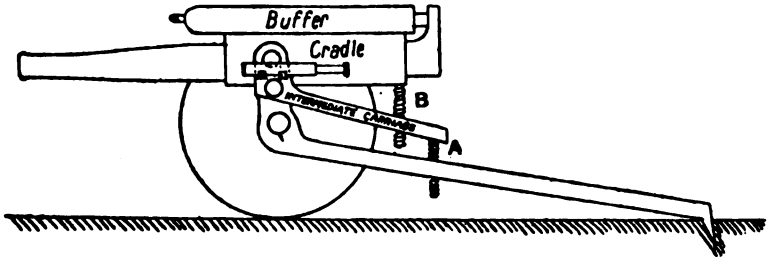

DIAGRAM ILLUSTRATING THE INDEPENDENT LINE OF SIGHT.
FIG. 23.

Let the gun in its cradle be mounted on an intermediate carriage, elevated and depressed by the screw "A." The telescopic or ordinary sight is fixed to this intermediate carriage. The gun and cradle are elevated and depressed by the screw "B."

To lay the gun, the layer works the laying screw "A" until the telescope points at the target; the gun also, if no elevation has been put on, is then pointing straight at the target. To give the gun the elevation necessary for the range, the elevating number on the right of the gun now works the elevating screw "B" till the gun is sufficiently elevated, the amount given being shown in yards on a drum connected with the elevating screw.

This motion given to the gun does not disturb the intermediate carriage with the telescope attached to it, and the telescope still remains layed on the target.

Once the sights are layed on the target, the elevation of the gun may be changed in a moment by a turn of the elevating wheel, without disturbing the laying. The layer does not have to concern himself about the elevation; he has only to keep his sights on the target while the other numbers continue the service of the gun.

This device is especially valuable when firing at moving objects, when the range and the laying have to be altered simultaneously.

The same result may also be obtained by other mechanical devices without the use of the intermediate carriage. Suppose a long elevating screw, with the sight connected to its centre, the lower end passing through a nut at the side of the trail, the upper end through a nut at the side of the cradle. Then if the lower nut be turned by the laying wheel, the screw, the sight and the gun will go up or down together; if the upper nut be turned by the elevating wheel, the gun will go up or down the screw without moving the sights.

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Page 23.—Colonel Scott's "automatic" independent line of sight gear also eliminates drift and dfference of level of wheels. See page 303.

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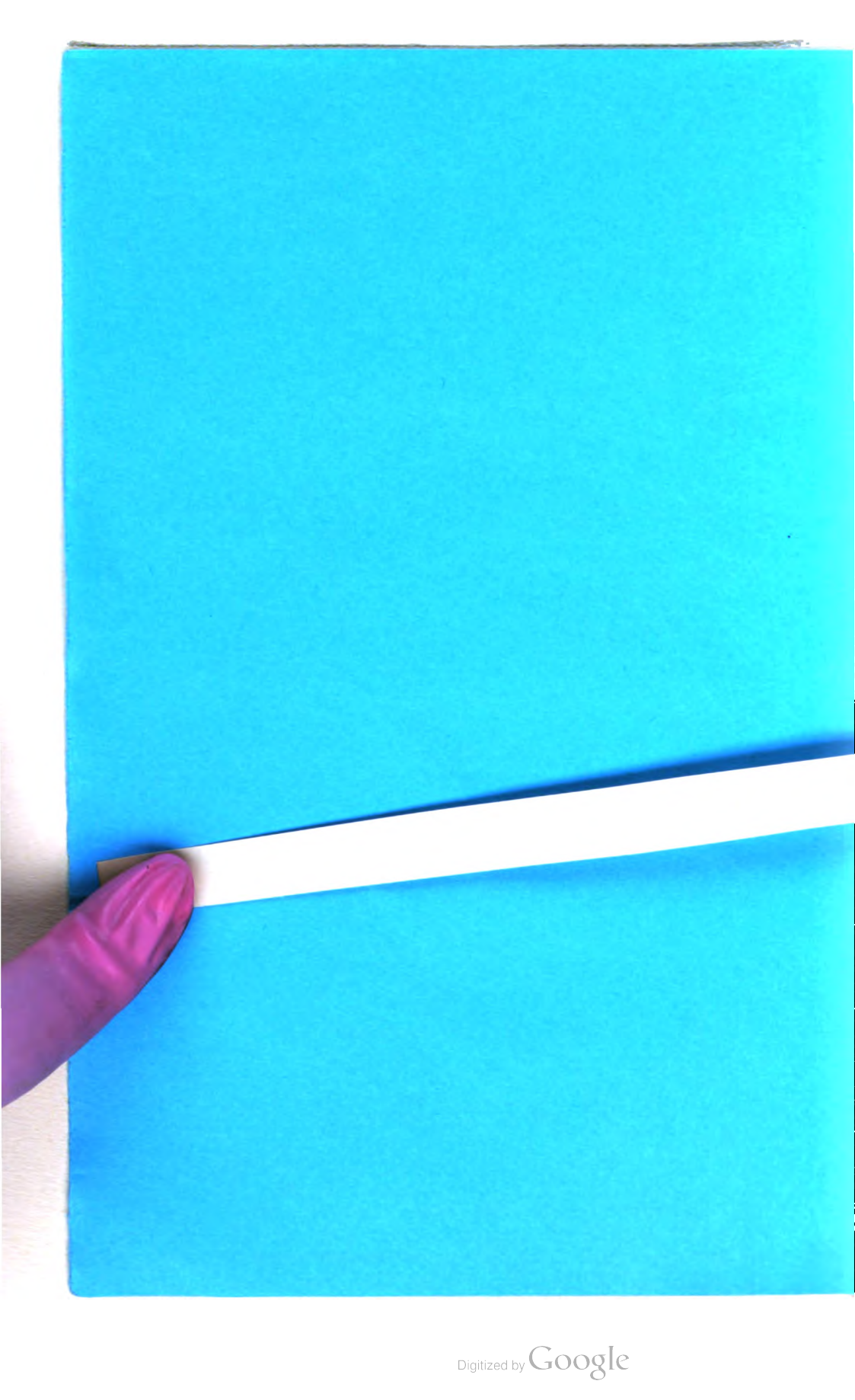

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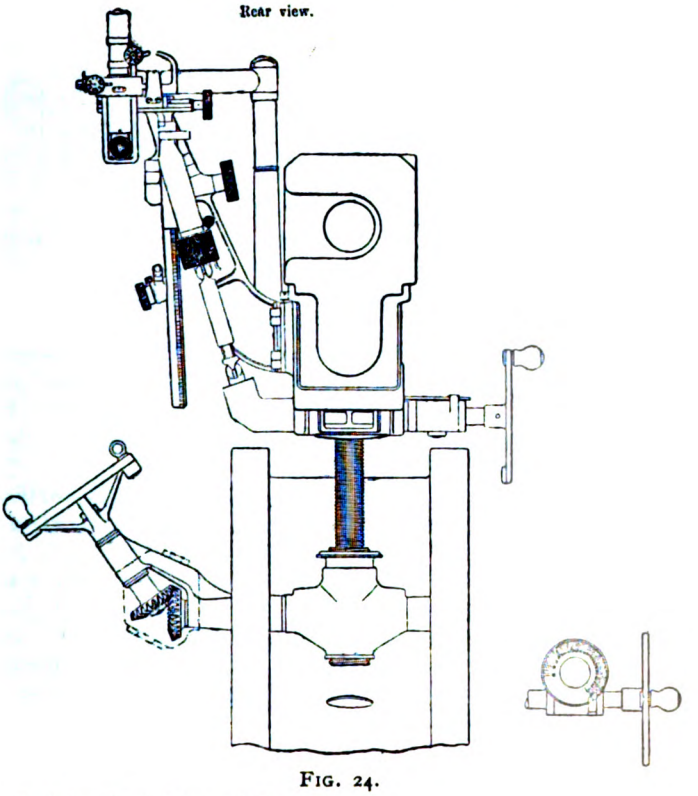

FIG. 24.

Krupp's Independent Line of Sight.

This ingenious gear has an advantage over other forms in that the sight is fixed to the cradle, not to the carriage. This enables it to inclined to correct for drift and cross-levelled to allow for difference of level of wheels.

In Fig. 24, which shows the Krupp gear, the inner telescopic elevating screw is turned by the wheel on the right, the outer by the wheel on the left. The latter motion elevates the gun and sights together. But the right-hand wheel elevates the gun without moving the sight. For it is connected to the sight by the connecting-spindle shown in the figure so that as the gun is screwed up the sight is screwed down, and remains in the same place.

The connecting spindle is telescopic and has two universal joints, which enable the sight to be revolved about a pivot parallel to the axis of the gun in order to cross-level it.

CLINOMETERS.

A clinometer is usually a spirit-level mounted in a frame so as to be capable of any desired amount of inclination to the horizontal plane.

In the Watkin clinometer the level is mounted on trunnions at one end, the height of the other end being controlled by a drum working on a screw. This drum is graduated spirally in degrees and minutes.

This form of clinometer is now-a-days being superseded by the simpler *arc clinometer.*

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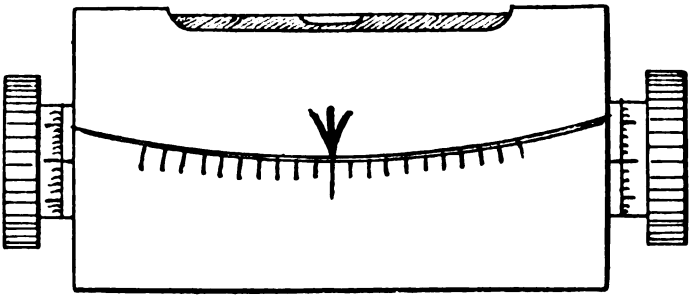

FIG. 25.

The upper block which carries the level, and the lower block, which is flat at the bottom, are capable of sliding on one another, the surfaces in contact being circular curves. The upper block is traversed by a tangent screw with micrometer head divided into minutes; the degrees are marked on the face.

It is immaterial whether the circular arc is fitted vertically or horizontally. In the arc sight already described the level is simply fixed to the head of the arc and the necessary inclination is given to the level by raising or lowering the arc through the requisite number of degrees. In this case the arc is so large as to afford plenty of room for small sub-divisions, and a micrometer screw becomes unnecessary. In the latest equipments the clinometer is fixed to the side of the arc, low down, so that the layer can see the bubble without rising from his seat.

The Adjustable Level.

All modern gun sights are fitted with a level adjustable for angle of sight. Thus, in the arc sight the level is not rigidly attached to the sight bar, but has a separate motion of elevation and depression, controlled either by a drum or by an open scale and micrometer head. The object of this device is to enable the sight to be always set at the elevation due to the range, which, except with howitzers, is invariably given in yards or metres. The allowance necessary for firing from behind cover at an object above or below the gun is given on the adjustable level.

Similarly, in guns fitted with the independent line of sight, an adjustable level is attached to the intermediate carriage or to the sight bar. When using clinometer laying the angle of sight is set on this level, while the elevation due to the range is given on the elevating drum.

The use of the adjustable level is further explained in the chapter on the Angle of Sight.

The Battery Telescope.

Under the heading of sights we may also class the battery telescope and stand.

The telescope itself, as issued to the English Artillery, is not in any way remarkable. It is a two-draw telescope with a pointer in the field enabling the telescope to be accurately directed on a given point.

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The telescope is secured by a spring catch to the tripod stand. This has a horizontal pivot which enables the telescope to be moved up and down in a vertical plane, with a level attached by which the vertical angle, or angle of sight, can be measured. This level has a degree scale and a vernier reading to 10 minutes. The telescope is mounted on a base-plate which revolves on a circular base, graduated on each half of the circle from 0 to 180°. There are two clamps, one for clamping the telescope to the base-plate, the other for clamping the base-plate to the horizontal circle.

To measure the angle between two objects, clamp the base-plate at zero; point the telescope at one object and clamp it to the base-plate, and swing telescope and base-plate round together till the telescope points at the second object; then read off the angle.

For accurate work the base-plate should be levelled by the use of the level attached to the telescope pivot.

The Director.

This is merely a sighted ruler mounted on a tripod stand identical with the telescope stand.

The Gun Arc.

This is a long cross bar set on the foresight and graduated for deflection to 30° right and 25° left. With the introduction of the goniometric sight the gun-arc has happily become obsolete.

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CHAPTER IV.

RIFLING.

Rifling is a means of imparting rotation to the shell. In all modern guns this is effected by cutting spiral grooves down the bore, leaving raised ribs called "lands" between them. A band of soft copper is secured round the shell near the base. On discharge the shell with its copper driving-band is projected up the bore; the ribs cut into the soft copper and force the shell to follow their spiral course and to rotate. This rotation continues, only slightly diminished by the friction of the air, to the end of the shell's flight.

Other means of making the shell rotate have been used, such as the tail with spiral vanes which rotates the torpedo shell fired from the Zalinski dynamite gun.

The only method of rifling now in use is however the polygroove system (so called from the large number of small grooves) and the copper or bronze driving band.

Uniform and Increasing Twist.

It will readily be understood that if a heavy shell has a high velocity of rotation suddenly forced upon it, this must cause a severe strain both on the shell and on the gun. To avoid this, the grooves of the rifling are made to run at first straight down the gnn, gradually increasing in inclination or "pitch" till the full velocity of rotation is attained. This is known as an "increasing twist," in contra-distinction to the older "uniform twist," in which the pitch of the rifling was the same all down the bore.

The increasing twist has however the disadvantage of causing greater friction in the bore and consequent loss of velocity. For the indents made by the lands in the driving band have to be forcibly displaced as the shell travels down the bore and the inclination of the lands alters. For this reason the uniform twist has been adopted in the new 18 pr. and 13 pr. guns.

As a good modern example of increasing-twist rifling we may take the 15 pr. Q.F. gun, the rifling of which is officially described as follows—

System—Polygroove.

Twist—Increasing from 1 turn in 60 calibres at breech to 1 turn in 25 calibres at 5.8 inches from muzzle; remainder uniform, 1 turn in 25 calibres.

Length—77.67 inches.

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Object of Rifling.

Any rapidly-rotating body tends to preserve the direction of its axis of rotation—that is, to keep in the same direction in which it pointed when first made to rotate. A familiar instance of this is the spinning top. (See Text Book of Gunnery, page 157.)

Not only does a spinning body tend to preserve the direction of its axis of rotation when left alone, but it actively resists any attempt to change that direction.

Thus, if we attempt to upset a spinning top by striking it with a ruler, we shall find some difficulty in doing so. Instead of overturning, the top will fly off sideways, still keeping vertical.

This property of rotating bodies is turned to account to make the shell travel point first during its flight. But for the spin given to the shell it would soon turn over and fly sideways, when its direction would become erratic and its range would be much reduced.

The object of rifling may, then, be said to be to enable a gun to fire an elongated projectile with accuracy.

Advantages of Elongated Projectiles.

Since a shell three calibres long has a cross-section only one third of that of a spherical shell of the same weight, it can be fired from a much smaller and lighter gun. And since it only opposes to the air a resistance one-third of that of the spherical shell, it ranges much further. And moreover since in penetrating an obstacle it makes a hole only one-third the size of that made by a spherical shell, it will penetrate more readily.

These advantages may be said to be due to rifling, which renders it possible to use the elongated shell.

Twist of Rifling.

A spinning top is acted on by its weight, which constantly tends to make it fall flat, and its energy of rotation, which keeps it vertical. When, owing to the friction of the peg of the top, the energy of rotation is sufficiently diminished, the top overbalances.

Now with a shell the force tending to overturn it is the pressure due to the resistance of the air, and that tending to keep it straight is the rotation due to the rifling. The former tends to constantly diminish as the shell expends its velocity in overcoming the resistance of the air; but the spin is affected only by the surface-friction between the shell and the air, and is very little reduced. For flat trajectories, it follows, then, that if we give the shell enough spin to keep it straight at starting, this wlll suffice to keep it point foremost to the end of its flight.

Minimum Twist.

The longer the shell in proportion to its diameter, the greater the amount of spin required. It will be afterwards seen that it is desirable not to allow an undue amount, as this increases the lateral curvature of the path of the shell.

A table of minimum twist of rifling required to keep steady a shell of any given length will be found at page 158 of the Text Book of Gunnery, 1902. As an instance, it may be noted that a shell 3½ calibres long requires a twist of at least one turn in 36 calibres to keep it steady.

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DRIFT.

This is a very difficult and complicated subject. We know that the service shell tends to deviate from the line of fire in a curve to the right, but we do not fully understand the laws governing this motion.

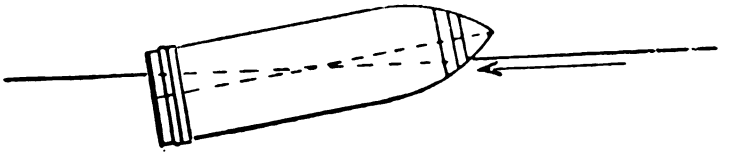

FIG. 26.

Although the effect of the resistance of the air tends to keep the shell pointing in the direction of its motion, yet the spin of the shell constantly resists this tendency, and tries to keep the shell parallel to its original direction, as in the above figure. The result is a compromise, and the shell travels with its nose cocked in the air, well above the line of the trajectory. It will be apparent from the figure that the full pressure of the resistance of the air comes below the point of the shell, as at A.

Now if we remember that the shell, viewed from behind, is spinning in the direction of the hands of a clock, then it will be evident that its friction against the air resistance, which takes it below the centre, must tend to make the shell gradually deviate to the right. And since the spin of the shell remains nearly constant while the forward velocity continually diminishes, therefore the path of the shell curves more and more to the right.

Thus if we suppose that the spin of the shell carries it ten feet to the right every second, then in the first second the shell will travel say 1500 feet forwards and 10 feet sideways, and will have acquired a side velocity, at right angles to the line of fire, of 20 feet per second. During the next second this side velocity will increase to 40 feet per second, during the next to 60 feet, and so on; while all the time the forward velocity will be decreasing. It is quite conceivable that if the range were long enough and the twist sharp enough the shell would end by drifting almost square across the line of fire.

A good distance of drift is the behaviour of a sliced golf ball. Here we have a projectile roughened so that the effect of the twist makes itself fully felt, a comparatively low velocity, and a sharp spin; and the result is often that the ball pitches nearly as far off the course as it carries from the tee.

It must not be supposed that the above is either a full account or a mathematically correct statement of the behaviour of a rifled projectile. It merely furnishes a working hypothesis sufficiently near the truth for the purposes of the practical gunner. Students desiring fuller information are referred to the Text Book of Gunnery.

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CHAPTER V.

THEORY OF CONSTRUCTION OF CARRIAGES.

The manufacturing details of carriage construction are beyond the scope of this book. The theoretical considerations on which the design of the carriage is based are, however, just as important from a gunnery point of view as those governing the design of the gun.

A gun-carriage is required to perform two principal duties—

First, to carry the gun and gun-shield across country without breaking down.

Secondly, to stand steady while the gun is being fired.

Considered as a travelling support for the gun, the carriage may be divided into three principal parts, the trail, axle-tree, and wheels.

The Trail.

The trail is merely a draw-bar, coupled to the limber by an eye-joint which allows of free lateral and twisting movement. It is this flexible connection which constitutes the difference between a gun-carriage and a four-wheeled carriage such as a G.S. wagon, and enables the former to travel easily over rough ground. The flexible connection has the disadvantage that the weight of the pole is not supported by the structure of the carriage, but must be borne by the horses. The portion of the weight carried by the horses varies according to the balance of the carriage, which is liable to be constantly disturbed by the movements of the men on the limber or by accidents of ground. For this reason a G.S. wagon travels better along the smooth surface of a road than a gun-carriage or an ammunition wagon.

Accordingly we find, in modern equipments, that all ammunition and stores except such as are required to be constantly present in the fighting-line with the guns are carried in G.S. wagons.

The Axletree.

This, in modern guns, is a drawn steel tube tapered at the ends to receive the wheels. It presents no constructional features of interest.

The Wheels.

The design of the wheels is of the greatest importance to the mobility of the carriage.

In the first place, a wheel should be as large as possible, in order to travel easily over small irregularities. A six-inch wheel drawn over a piece of corrugated iron would drop into each corrugation and

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have to be pulled up each succeeding slope, while a 60-inch wheel would run over the tops of the corrugations without any perceptible drop between them.

Of still greater importance is the distance to which the small wheel sinks into the ground as compared with the large one. Suppose the ground such that a pressure of 56 pounds on the square inch compresses it to a depth of 1 inch, and compare a 3 ft. and 5 ft. wheel, each 3″ broad, under these conditions. Suppose the weight on each wheel to be 10 cwt., then each wheel will sink into the ground till the total resistance of the ground to crushing is equal to 10 cwt. Suppose this resistance to increase uniformly, which is practically the case for small depths; then in each case the amount

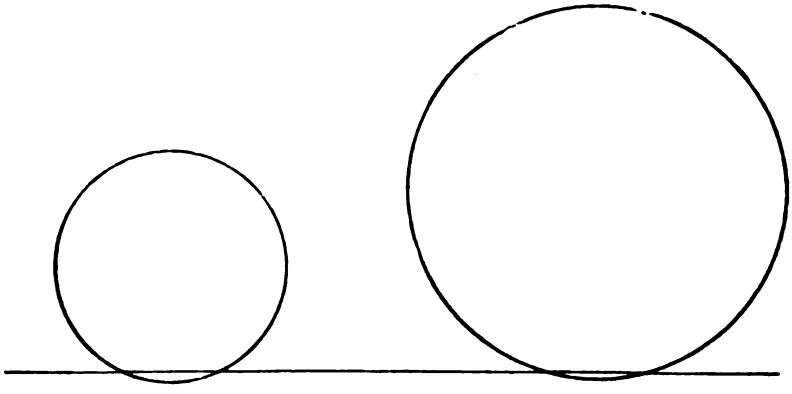

FIG. 27.

of the upward pressure of 10 cwt. will be represented by the area of the segment below the ground surface. In other words, the wheel may be considered as a transverse slice of a ship floating in water.

Let us assume that the "immersed section" of each wheel is 10 square inches, which is about the case with a gun-wheel on moderately soft turf, and let us compare a three-foot wheel with a five-foot one. With the assistance of the trigonometry book and table of log. sines we determine that the width of the immersed segment is 13″ for the 3 ft. wheel and 15·5″ for the 5 ft. one; the depths are 1·20″ and 1.05″ respectively. That is, the small wheel sinks only 0.15″ deeper than the large one. This is a small matter so long as the wheel is at rest. But when it begins to advance the difference becomes a serious one.

Since the effect of the wheel in crushing the earth is represented by the area of the "immersed segment," and the area of a segment (or any other figure) of definite shape varies as the square of its dimensions, this is equivalent to stating that the work done by the wheel is proportional to the square of the depth of the rut. The effect of the work done by the horses is to make a rut 1.05″ deep for the large wheel as against 1.20″ for the small one. That is, the work is as (1.05^2) for the large wheel to (1.20^2) for the small one, or as 1.103 to 1.44. The difference is .337, or 30.6 per cent. of 1.103. That is, in this case the small wheel requires 30.6 per cent more power to pull it than the large one.

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It is hardly necessary to say that the above investigation does not give a complete account of the facts. For instance, the compression of the earth has been assumed to take place indefinitely slowly. Now we know from the theory of dynamics that more power is required to shift the particles of earth quickly than to do so slowly. Therefore the amount of power wasted by the small wheel increases as the speed increases. This is the reason why vehicles required to travel at speed have larger wheels than slow-moving ones, as in the case of a hansom and a growler.

Another fact which further handicaps the small wheel is that, from the sharper curve of the tire, it tends to throw up a wave of mud or soft earth in front of it, over which it has to travel.

From the point of view of the battery horse and his Major it therefore follows that the wheel should be as large as possible. In practice the diameter of the wheel is limited by the increase of its weight and of the weight of the extra long trail required to preserve the same trail-angle. This point will be investigated in the chapter on the steadiness of the carriage.

The diameter of the modern English gun wheel has been fixed at 4 feet 8 inches.

DRAUGHT.

For a gun and limber weighing, with detachment, 2 tons, running on 4′ 8″ service wheels, the draught may be approximately estimated as follows—

Hard dry macadam	80 lbs
Good but gravelly macadam ...	100 ,,
Unmetalled road, fair condition ...	150 ,,
Ditto, bad condition	200 ,,
Stiff muddy clay road	500 ,,
Sand road	700 ,,

The above figures represent the pull required to keep the carriage going at a walk. On a good hard road, the draught at a trot is but little greater than at a walk; but on bad roads the draught is heavier at a trot. It may be noted that Messrs. Hancock & Gurney, road coach proprietors, found that their coaches ran better above four miles an hour than below that speed.

SPRINGS.

It is generally estimated that on ordinary roads the horse-power required to draw a carriage mounted on springs is only half that for a carriage without springs. The saving is greatest when the road is rough and gritty, so as to keep the springless vehicle in a constant state of jarring vibration. On deep heavy roads, springs make little difference.

Since nine-tenths of Artillery work on service is done on ordinary roads, it would therefore be an advantage to mount guns, limbers, and wagons on springs. This would enable the present six-horse team to be replaced by four-horse teams, keeping one pair spare for heavy roads. It is not improbable that we shall see this reform carried out before many years have passed—even if, by that time, the

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battery horse has been replaced by a motor-tractor. But, so far as, the writer is aware, no attempt has yet been made to mount the gun-carriage on springs.

As regards the wagon and limber, however, several experimental equipments with springs are in existence, both American and Continental. The plan usually adopted is to interpose rubber blocks between the ammunition box and the axle-tree. These blocks, when compressed, are about 6 inches in diameter and 4 inches high. The ammunition box is bound down to the axle-tree by shackles or short lengths of chain.

There is no doubt that this plan makes the carriage ride easier and saves the horses. But the practical difficulty is that the violent jerks which occur in travelling over bad ground tend to break the shackles or tear them from their attachments. An equipment of this nature was subjected to travelling trials by the American Government in 1903, and this particular equipment was condemned as unserviceable for the reason stated. This failure must not, however, be regarded as final.

It is possible that the difficulty may be got over by introducing additional rubber blocks below the axle-tree, so as to afford an elastic attachment for the shackles.

Spring Draught.

Before the general introduction of swingletree draught, spring draught-loops on the splinter-bar were used with great success, and were found to save collar-galls, especially on the wheelers. This purpose is now to a great extent served by the swingletree, and it is not thought worth while to incur the extra weight and complication of a spring attachment for the swingletree.

Spring Limber Hook.

A spring connection between gun and limber has often been advocated, and is actually used in the French Q.F. field gun. The French contend that the extra weight of the spring attachment is more than compensated for by the weight which can be saved in the limber owing to reduction of travelling strains.

The general view taken of the matter by most Artillery authorities is that all these spring contrivances for reducing draught are unnecessary on good roads—since the draught is then well within the power of the team—and worse than useless on very bad roads, or across country. It is not considered worth while to provide them for the sake of relieving the horses on indifferent roads.

Should a great Continental war break out, in which the guns have to traverse great distances, it is possible that the heavy expenditure of horseflesh may cause the above opinion to be modified.

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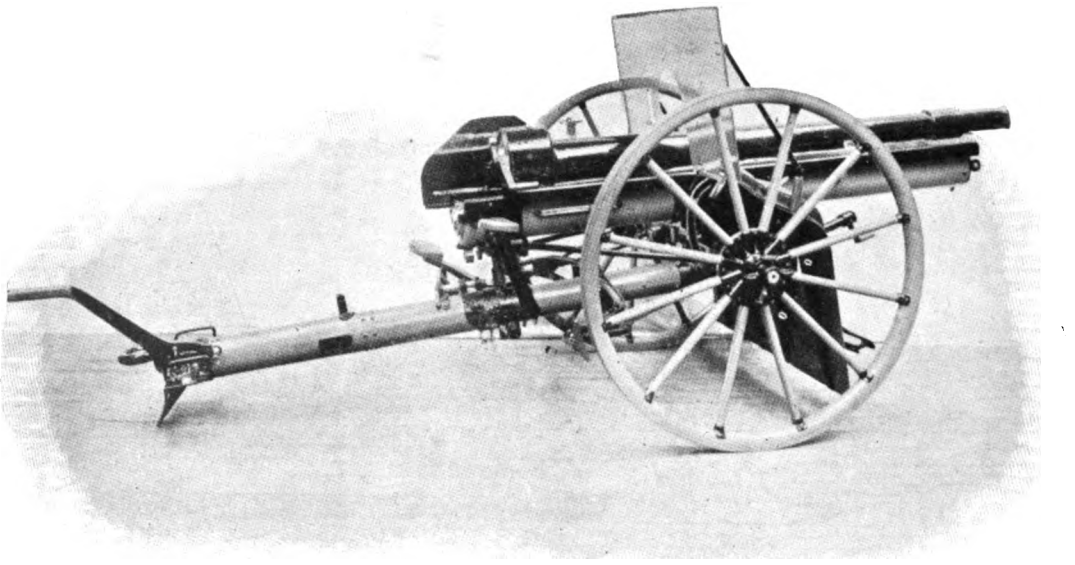

75 mm. FIELD GUN WITH ECCENTRIC SCREW BREECH ACTION.
EHRHARDT.

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CHAPTER VI.

THE GUN-RECOIL CARRIAGE.

General Principles.

A modern carriage is expected to stand steady on firing, so that in the first place it requires no running up, and in the second place it maintains the direction of the gun so that only a slight correction in elevation and direction is required after each round. The carriage is maintained in position by the spade, which sinks into the ground, and by the friction of the wheels upon the ground. If however the force of the recoiling gun were communicated directly to the anchored carriage, the effect would be to make it jump violently, which would not only disturb the laying but prevent the layer and elevating number from sitting on their seats. The hydraulic buffer is therefore interposed between gun and carriage. If the gun were rigidly attached to the carriage, the latter would be forced back perhaps half an inch at each round, and the whole of the recoil-energy would have to be absorbed in that half inch of motion. Instead of this, the gun alone is allowed to recoil through four feet or so, and though the recoil-energy is in this case greater than it would be if gun and carriage recoiled together, yet it is so gradually communicated to the carriage that instead of a violent jerk we have a steady uniform pull, the only effect of which is to slightly compress the earth behind the spade.

In a well-designed equipment the amount of this pull is always less than that required to lift the wheels off the ground by tilting the carriage about the fulcrum, namely the spade.

The only motion of the carriage which takes place is therefore that due to the elastic bending and rebound of its parts under the cross strains set up on discharge. These strains are inevitable, since the direction of recoil cannot always be exactly in the line of the resistance of the earth behind the spade. One ideal form of carriage would be to have the trail hollow and the gun recoiling inside it; the elevation would then be given by raising and lowering the front of the carriage. Such a form is impossible if only because the layer would have to raise the whole weight of gun and carriage when giving elevation. Instead of this we have to be content with so adjusting the proportions of the carriage that at ordinary elevations the line of motion of the centre of gravity of the recoiling parts falls as nearly as practicable in the centre of the spade.

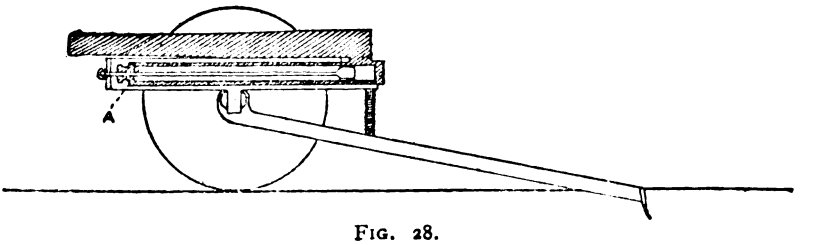

FIG. 28.

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Action on recoil.

The above figure shows diagrammatically the arrangement of a modern German Q.F. carriage, being taken from the Ehrhardt equipment. The buffer is made to recoil with the gun, because, as explained in the chapter on recoil, the greater the weight of the recoiling parts the less the recoil-energy which has to be absorbed. The action which takes place on recoil may be thus briefly described:

The average velocity of the shell up the bore being $\frac{1640}{2}$ foot-seconds and the recoil-velocity imparted to the gun being 30 foot-seconds, then before the shell has left the muzzle the gun will have recoiled, roughly speaking, some 1½ inches. (It will really have recoiled for a less distance, since it does not attain its full recoil-velocity till after the shell has left the muzzle.) It is the behaviour of the gun during those first 1½ inches of recoil which effects the accuracy of the shooting. Now when the buffer-cylinder is drawn back from the piston the first thing that happens is that the air at A in the front of the buffer is compressed, so that for the first couple of inches the resistance to recoil is slight, and the gun moves back freely without feeling any resistance tending to alter its direction. When the air is fully compressed, the glycerine in the buffer begins to be forced past the piston through the grooves or *ports* in the walls of the buffer-cylinder, encountering a strong resistance in doing so. The amount of this resistance depends on the windage or difference of cross section between piston and cylinder, that is, on the area of the ports. By varying the depths of the ports at different points as required it is possible to adjust the resistance so as to be uniform throughout the whole recoil of the gun, thus keeping the maximum pull exerted by the piston-rod on the carriages as low as possible.

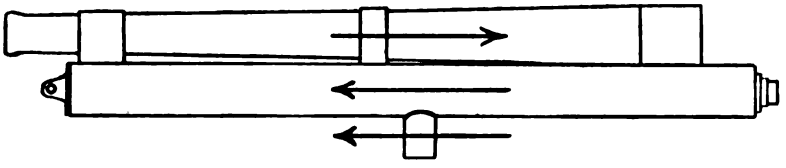

FIG. 29.

Cross Strains.

In an ideal equipment there would be two buffers, one on each side of the gun. This however would mean an increase of weight, and it would be difficult to balance the resistance in the two buffers, even if they communicated by a cross-tube. At the present time all field guns are made with a single buffer.*

Since the axis of the buffer must be at some distance from the axis of the gun, the resistance of the buffer is equal but not opposite to the force exerted by the gun; the two forces form a *couple*, as indicated by the arrows in the above figure, tending to revolve the gun clockwise, raising the muzzle and depressing the breech.

And again, in this particular form of gun, the attachment of the buffer to the axle-tree, namely the vertical trunnion on the cradle, is not in line with the axis of the buffer, but some inches below it. Here

* The Bethlehem Mountain Gun is an exception. See Part IV.

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we have another couple, also tending to raise the muzzle and depress the breech.

The fact that both these couples act in the same direction, tending to press on the head of the elevating screw and so bend the trail downwards, is in one sense an advantage. For owing to the preponderance the cradle presses firmly on the elevating screw, and owing to its weight the gun presses firmly on the cradle, hence there is no play or lost motion, and no risk of the downward pressure being converted into a blow.

On the other hand, the downward bending strain on the trail is undesirably heavy. For the whole system of gun, buffer, and cradle turns about the axletree, and the buffer is interposed between gun and axletree, rendering the distance between the gun and the pivot upon which it turns unduly great. That is to say that the force of the recoiling gun acts at the end of a comparatively long lever tending to break or bend the trail, which has to be made stiff and heavy in order to stand the strain.

Hence we find the tubular trail, once so popular, being replaced, in equipments of this description, by trails of box or girder section. The tubular trail is strongest all round, but since the strength is principally required to resist a vertical bending strain it is found better to use a form giving more vertical and less lateral stiffness. In the Ehrhardt 1903 equipment, for instance, the original cylindrical trail is replaced by one of U section.

We will now consider another type of carriage, illustrated in the annexed figure.

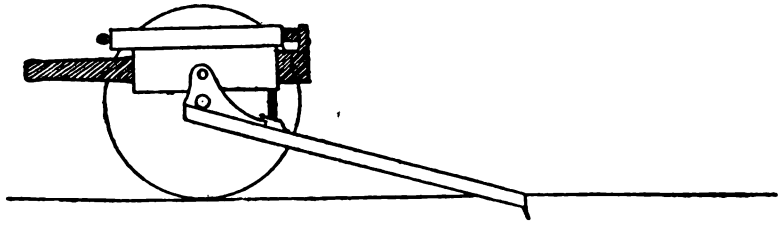

FIG. 30.

Top-buffer Carriages.

In this case the gun is between the buffer and the axletree. The recoil of the gun being resisted by the pull of the buffer, a *couple* is formed tending to raise the breech and depress the muzzle of the gun. On the other hand, since the buffer is attached to the top of the cradle, the pull of the buffer tends to revolve the cradle (containing the gun) about its trunnions in the opposite direction, raising the muzzle and depressing the breech. Since the trunnions of the cradle are on a level with the axis of the gun, these two couples are equal, so that the only strain on the elevating screw should be that due to the weight of the gun when in the recoil position. On the other hand, since the trunnions of the cradle are at a considerable distance from the axis of the trail, the direct pull on these trunnions tending to bend the trail, as distinguished from the downward pressure of the elevating screw, is more effective than in the first-described system.

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Effect of Wear.

One objection to the top-buffer system is the irregular action which takes place as soon as the bearing surfaces begin to wear. When the guide-ribs supporting the gun in the cradle, or the surfaces on which they rest, get worn, then the gun lies loosely in the cradle. Since it is held back from recoiling by the horn on the top of the breech attached to the buffer, the first motion of the gun on firing is to tip up, the breech jerking upwards and the muzzle down.

If there is also play at the trunnions of the cradle, the effect is here to jerk the muzzle upwards. Whether these two opposite actions take place simultaneously or no is a matter dependent on the friction between the surfaces, which is a variable quantity. Hence it is impossible to predict whether the upward or downward jerk will predominate. The actual displacement may only be a matter of hundredths of an inch, but this makes a good deal of difference at the target end of the range.

Tilting Strains.

These have been purposely placed after the cross strains in order of importance, since in a well-designed equipment they are rendered ineffective by a judicious distribution of weights and dimensions.

The effect of firing a gun mounted on an anchored carriage is to tend to turn that carriage over backwards about the point of the trail. This tendency is resisted by the weight of the gun and carriage, which must be sufficiently great, in comparison to the force of recoil, to keep the wheels from lifting off the ground on discharge. Since the ordinary force of recoil in modern Q.F. guns is not far short of two tons, while the weight of the gun and carriage does not exceed one ton, the carriage must be so constructed that the weight acts at considerable mechanical advantage. This mechanical advantage is supplied by making the trail so long that the horizontal distance from the spade to the centre of gravity is at least double the vertical distance from the spade to the axis of the gun.

Before investigating the question of the stability of the carriage, it is as well to warn the student that this subject involves problems which cannot be solved by elementary rules of statics. The equilibrium of the carriage under the pull of the buffer-rod is a simple matter, if we assume the carriage to be rigid. But the action which takes place between gun and buffer-rod is complicated by questions involving the inertia of moving bodies, which require to be treated by higher mathematics.

For ordinary practical purposes it is usual, in estimating tilting strains, to assume that the carriage is a rigid frame pivoting about the centre of the spade, and acted on by the force of recoil through the C.G. of the recoiling parts, and the force of gravity acting through the C.G. of the system.

The gun is supposed to be layed horizontal, and the centre of gravity is taken in the position least favourable to steadiness, that is when the gun is at extreme recoil.

We will apply this simple method to determine the stability of the 15-pr. Q.F. gun.

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We have first to determine the force of recoil. The recoil energy (see Chapter XVII.) is 5.3 foot-tons. This energy is absorbed during a recoil of 3½ feet, so that the average pull on the carriage is $\frac{5.3}{3.5}$ tons or 1½ tons. In this gun the buffer-ports are so adjusted as to make the pull nearly uniform throughout, and the maximum pull at any point of recoil does not exceed 1¾ tons. The height of the centre of gravity of gun and buffer is 3.2 feet, or 3.45 feet vertically above the centre of the spade; therefore the overturning moment, which is the pull multiplied by the distance from the fulcrum at which it acts, is 1¾ × 3.45 or 6.0375 foot tons.

This overturning moment is opposed by the weight of the gun, which is 18½ cwt., acting at a distance of 7¼ feet from the fulcrum, thus giving a steadying moment of 6.7 foot tons.

Since the overturning moment is only 6.0375 foot tons, the carriage will remain steady on discharge. It would still remain steady if the steadying moment were only 6.0375 foot tons, that is, if the weight were reduced 2 cwt. Practically, however, the whole of the surplus stability is required to keep the carriage steady under disadvantageous circumstances, as when firing from a reverse slope, when the vertical distance of the gun above the spade is greater than on level ground. Moreover a certain amount of extra stability is required to counteract the elastic rebound of the carriage on discharge, due principally to the spring of the long trail. It is accordingly customary in modern Continental practice to allow a surplus stability of about 3 cwt. in addition to the amount as determined by the rough method given above.

It should be noted that if once the wheels begin to lift during recoil the height of the gun above the spade is increased, and the leverage of the overturning force is augmented, so that the wheels will continue to lift till the end of the recoil.

Another method of determining the stability is to take the gun in the mean or half-recoil position, measure the distance of the centre of gravity of the recoiling parts from the centre of the axletree, and thence calculate the weight on the wheels. The diagram of stability for all positions of recoil is given at the end of this Chapter.

Attachment of Buffer.

It is found in practice that the point of attachment of the buffer to the carriage has considerable effect on the steadiness. This point should be as low as possible, and should be in line with the prolongation of the trail. This saves cross strains and bending strains and reduces the elastic rebound of the carriage.

Position of Buffer.

The buffer may be either above or below the gun. The former construction, which is adopted by Elswick and Vickers-Maxim, enables the gun to be 6 inches lower on the carriage, and so reduces the overturning moment. On the other hand, the position of the attachment of the buffer to the carriage is unfavourable to steadiness, and the accuracy of the gun is liable to be affected by wear of the slides, as already pointed out.

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The construction with buffer under the gun is used by all American and Continental gunmakers, who claim for it strength, simplicity, and a higher degree ot steadiness than is attained by the English makers. Certainly the 1906 Krupp and Ehrhardt guns, which have the buffer in a cradle under the gun, leave nothing to be desired on the score of steadiness in action.

Shifting Centre of Gravity.

When the gun is in the forward position, at the beginning of recoil, the centre of gravity of gun and carriage is further forward than at the end of recoil, and the steadying moment is greater. It is therefore permissible to adjust the depth of the ports so as to oppose a greater resistance at the beginning of recoil than at the end of recoil.

Another method of adjusting the buffer-resistance to the curve of stability is the system of controlled recoil discussed in Chapter VIII.

Height of Wheels.

To give the greatest mechanical advantage in resisting the over-turning pull of the buffer, the trail should be as long and the wheels as low as possible. The relative proportion of these two dimensions gives the *angle of the trail.*

In the French equipment, for instance, the wheels are 4′ 4″ and the trail 9′. The proportion is therefore as 26″ (the height of the centre of axletree) to 108″ (the length of the trail measured on the ground line.) This gives a trail angle of practically 1 in 4.

Modern German makers consider this angle too steep, and make the trail longer, giving a more gradual slope. But assuming for a moment that the French angle is correct, it will be seen that any increase in the height of the wheel makes a four-fold increase in the length of the trail. Not only is this so, but the weight of the trail increases, not directly in proportion to the extra length, but as the square of the length. For to maintain the same strength the long trail must be made stouter than the short one.

This is the reason why Continental manufacturers, who are obliged by the requirements of their customers to produce a perfectly steady gun weighing less than one ton, have cut the wheel down to the lowest possible dimensions.

Cranked Axletree.

It is possible to reduce the trail-angle and still keep a high wheel by cranking the axletree, or bending it downwards in the centre. This construction is used in the German and Russian field guns and in some of the Krupp howitzers. The cranked axletree is weaker than a straight axletree of similar section, and it is not found possible, without a large increase of weight, to save more than 3 inches of height by this method.

Modern Requirements as Regards Steadiness.

On the Continent, steadiness is all the fashion now-a-days. That is to say that other and possibly more useful qualities are sacrificed in order to obtain such a degree of steadiness of the gun and carriage

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as will enable six or more rounds to be fired without its being necessary to relay the gun. Thus in the Swiss 1903 competitive trials one of the principal "events" was a series of 12 rounds fired without re-laying, and the success of the Krupp gun in this series was one of the chief reasons assigned by the committee for its selection as the Swiss Field Artillery weapon.

The French Field Artillery gun, which was the pioneer of all Q.F. field-guns, was and is perfectly steady in firing; but it weighs nearly 23 cwt. unlimbered, and its brake gear and recoil gear are decidedly cumbrous. In more recent Continental guns the object of the makers has been to secure steadiness equal to that of the French gun combined with greater simplicity and less weight.

Steadiness in a gun-carriage may be arrived at by reducing the weight of the shell, reducing the M.V., or increasing the weight of the gun; each of these methods reduces the recoil energy. Or it may be achieved by lengthening the recoil, which reduces the *average* strain exerted on the carriage, or by boring the buffer for uniform resistance, which reduces the *maximum* strain. And finally, resistance to tilting may be secured by increasing the leverage or mechanical advantage with which the carriage meets the strain. This is done by lengthening the trail, reducing the diameter of the wheels, and keeping both the gun and the point of attachment of the recoiling parts to the non-recoiling parts—*i.e.* of the buffer-rod to the cradle—as low as possible. The advantage gained in this way is apparent on considering Figs. 28 and 30, in which the recoiling parts are shaded.

Length of Trail.

The trail is now made much longer than heretofore. The original Ehrhardt trail was telescopic, 10.5 feet long when extended and 8 feet long when closed up. This construction has been practically abandoned, and Krupp, Ehrhardt, Schneider, Skoda, Elswick, and Vickers all turn out long non-telescopic trails. The round tubular trail has been improved upon, and Ehrhardt now makes trails of U section, while other makers mostly use the girder or box trail.

The length of the trail is limited first by the difficulty of getting sufficient elevation on a forward slope, and secondly by its weight. To be sufficiently rigid, a long trail must be stouter than a short one.

Since, therefore, the present fashion in gun construction requires perfect steadiness, we find the latest foreign models built with low wheels and abnormally long trails. A comparison of the different guns in this respect may be interesting.

(The trail measurement is from centre of axletree to centre of spade.)

	Wheels.	Trail.
Austria (1903 Experimental)	4′4″	10′
France (1898-1902)	4′4″	9′
Switzerland (Krupp, 1903)	4′3¼″	8′8″
Spain (Schneider, 1905)	4′4″	9′
America (Ehrhardt, 1903)	4′8″	10′6″
Denmark (Krupp, 1903)	4′4″	9′
Russia (1903)	4′5″	9′

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Hydraulic Buffers.

The art of boring the buffer so as to get perfect smoothness of recoil and perfectly-regulated pressure is a difficult and delicate one. Very little is known theoretically about the behaviour of a fluid forced through a narrow orifice under sudden and violent pressure.

The progress recently made in the art of buffer-boring is due to practical experiments with the pressure-indicator. This consists of a gauge connected with the interior of the buffer by means of a hollow piston rod so that the pointer rises and falls as the pressure in the buffer increases and diminishes. As the gun recoils, the pointer is made to trace a line upon the smoked surface of a strip of metal attached to the gun. Any irregularity in the pressure is recorded by undulations in the line.

By adjusting the resistance in the buffer, Messrs. Krupp were able in 1903 to reduce the dead weight in the new Swiss gun by 110 lbs., thus allowing of a substantial increase in the weight of the gun-shield.

Construction of Buffer.

The buffer is a steel cylinder about 2.75″ in external diameter, and 0.3″ thick. It is usual to fix the buffer to a horn projecting from the breech of the gun, and the piston-rod to the cradle, so that the buffer recoils with the gun. This increases the recoiling weight and reduces the recoil-energy. At the forward end of the buffer is a stuffing-box with gland through which the piston-rod passes. The buffer is nearly filled with oil or glycerine. The piston is a close fit in the buffer, and the oil or glycerine is forced past it on recoil through the ports in the inner surface of the cylinder. These ports are open channels, like the grooves of an old-fashioned rifled gun; they are about 0.4″ broad and 0.05″ deep. The effective length of the buffer is about one inch greater than the length required to absorb the recoil-energy. The gun should never be allowed to recoil till the buffer comes "metal to metal."

The ports have to be large at the commencement of the stroke to avoid any sudden jerk upon the carriage. But this leaves the gun uncontrolled at the end of the return stroke, so that, unless checked, it would run up with a jerk. It has therefore to be eased into the firing position by a check buffer. This, when used, takes the form of a smaller piston, fixed to the bottom of the buffer-cylinder, which enters a hollow in the piston-rod. But a more efficient means of regulating the run-up is the valve-gear described in the next chapter.

The Running-up Valve.

The resistance of the buffer to recoil is much greater than the slight resistance required to bring the gun gently to a standstill after running-up. If the buffer opposes the same resistance to running up as to recoil, then either the run-up is slow, or powerful running-up springs have to be used to overcome the buffer-resistance. To avoid the latter necessity the more recent Krupp and Ehrhardt buffers have a valve in the piston which allows the buffer-liquid to pass

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freely while running up. Either the opening in the piston leading to this valve is closed before the end of the run-up by a Vavasseur valve (see next chapter), or else the valve is pressed down by a spring behind it of sufficient strength to give the necessary resistance.

Air in the Buffer.

On recoil the piston is drawn out of the buffer, causing a partial vacuum within. There is then a tendency to suck in air through the gland every time the gun recoils. No air can get in during recoil, owing to the back pressure of the buffer-liquid against the gland; in fact, the vacuum formed is at the other side of the piston. But during the beginning of the running-up stroke, if the gland be not air-tight, a certain amount of air gets in. If this be repeated at every round the air may accumulate in the buffer in sufficient quantity to prevent the gun from fully running up. It might be supposed that the air would be all expelled on the recoil-stroke: but practically the air, once inside the buffer, gets churned up with the oil or glycerine into a thick froth which does not escape through the gland. The Russian equipment has an air-valve through which air accumulated in the buffer can be let off.

It is usually possible to keep the buffer-gland oil-tight, but it is not always easy to keep it air-tight on service, especially when the grease in the packing is frozen. The buffer is therefore not completely filled with liquid, but from 5 to 10 per cent. of air-space is left. The liquid becomes exceedingly hot during rapid firing, and ... would otherwise prevent the piston and piston-rod from going completely home. The air-space also serves the purpose of allowing free recoil until the shell has left the bore, as explained on page 34.

Page 41.—The action of running-up springs is further considered in Chapter XXX. See page 256.

Running-up Springs.

Till lately, these used to give trouble by collapsing, owing to the space into which they were compressed on recoil being too short. Messrs. Armstrong were the first to get over this difficulty by the use of the telescopic spring-case. (Patent No. 17176 of 1900.)

This device was used by Messrs. Krupp in their earlier Q.F. equipments, and is hence frequently referred to as the Krupp buffer. But the credit of its invention is due to Messrs. Armstrong. The principle of the buffer is as follows:—Suppose that the recoil springs of a gun occupy a length of 6 feet, and that the gun recoils 4 feet, then the springs are compressed into a space of 2 feet at each round. This treatment is liable to crush them. But if, as in the sketch

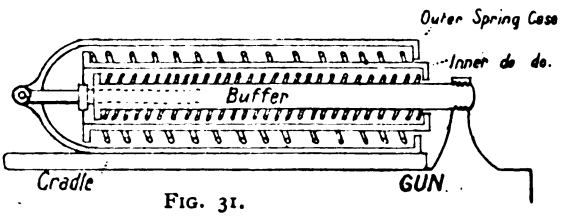

FIG. 31.

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(Figs. 31 and 32), we have an outer and an inner set of springs each 5 feet long, then when the gun recoils and the telescopic arrangement

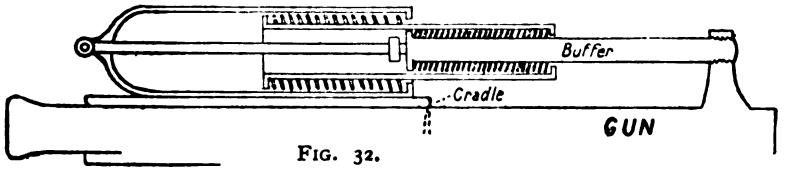

FIG. 32.

is pulled out each set of springs is compressed into a space 3 feet long, as in the second sketch. That is, the springs are now only compressed to 3/5 of their own length instead of to $\frac{1}{3}$ as before. It should be noted that these drawings are merely diagrammatic. As a matter of fact, the Krupp buffer is under the gun.

Several mechanical equivalents of the telescopic spring-case are in use.

Thus Messrs. Cockerill use a slide interposed between the gun and cradle. One spring, in tension, is between gun and slide, and the second set, in compression, between slide and cradle. On recoil the slide moves only half the distance that the gun moves, thus halving the strain on the springs.

Krupp Springs.

In the later Krupp equipments the makers have abandoned the complications of the telescopic spring-case and have reverted to the simple construction shown in Fig. 33.

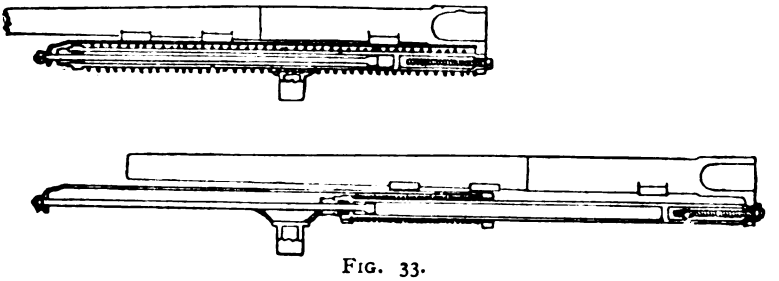

FIG. 33.

Here we have a single column of springs surrounding the buffer, and compressed between a collar on the front of the buffer and the rear plate of the cradle, much as in the Ehrhardt system. There are three parting-plates, and the one long column of springs is compressed into a space between a third and a quarter of its length, so that its coils are almost touching. The spring is of wire, of flattened section, and must be of excellent manufacture to stand this severe treatment. Messrs. Krupp, however, appear fully satisfied with the performance of this system, and have embodied in it all their new equipments, including those made for Switzerland, Denmark, and Holland.

Note in the figure the vertical trunnion by which the cradle is attached to the lower carriage, also the method of lightening the cradle by cutting away portions of it, leaving the springs exposed.

The screw at the rear end of the buffer is for the purpose of putting the initial compression on the springs.

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Ehrhardt Springs.

Messrs. Ehrhardt have always adhered to the single column of springs. They formerly used an extra long spring-case or cradle extending beyond the breech of the gun, in order to get as much length as possible. This has however been discontinued in their latest models. They have now a valve which relieves the springs of all buffer-resistance in running up, so that the effort is limited to that required to raise the weight of the gun when firing at angles of elevation. This enables lighter and more slender springs to be used, which do not suffer much from compression.

Initial Compression.

The German makers' rule is that this should be 80% of the weight of the gun. It is reckoned that, after making all practical deductions, one pound of spring can absorb and give out 40 foot-pounds of work.

Final Compression.

This varies considerably in different equipments; it is least when a running-up valve is fitted, which enables light springs to be used. In the Krupp field guns the initial compression is about 5 cwt. and the final compression from 12 to 15 cwt.

Hydro-pneumatic Recoil Gear.

The difficulty in getting a satisfactory direct-action running-up spring system led the designers of the present French gun to adopt the hydro-pneumatic system. In the original form of this gear the displacement of the liquid in the buffer cylinder was utilised to compress a column of air serving as a running-up spring.

French Gear.

The French gear is complicated, having three cylinders, two with pistons, and one containing the compressed air which replaces the ordinary springs. It has four stuffing-boxes, one ball-valve, and six cylinder covers packed and screwed on, which have all to be kept tight, besides a pump for keeping up the pressure. It does not seem probable that this construction will be repeated in any future equipment.

The Modern French H.P. Gear.

Messrs. Schneider, Canet & Co. have lately brought out a new hydro-pneumatic recoil gear, which is free from many of the objections adduced against the original type of this gear. It is especially well adapted for use in heavy field howitzers, where the weight and bulk of the running-up springs form a serious item.

The leading feature of the new system consists in the complete separation of the buffer from the running-up gear. In the earlier types, in which the two were combined, it was found impossible to keep the air and the liquid from mixing, so that the buffer, instead of being filled with oil, contained a sort of froth of oil and air which opposed irregular resistances to recoil. Moreover the buffer piston had to be kept tight under the full pressure due to the recoil, and the pressure of the air in the reservoir was correspondingly high.

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In the new system only one piston—that used for running the gun up after recoil—has to be tight, and the pressure of air is only sufficient to raise the weight of the gun when running up at maximum elevation.

A good example of the latest type of H.P. gear is that used in the 1905 Schneider-Canet (Creusôt) Spanish and Portugese field guns.

The cradle is under the gun; it is a solid steel forging, having four longitudinal holes bored in it, one forming the buffer-cylinder, one the running-up cylinder, and the third and fourth (which communicate with the second) the compressed air reservoir.

The buffer is of the usual modern construction. Messrs. Schneider adhere to the check buffer, although both Ehrhardt and (in his later constructions) Krupp have abolished it. The latter firms consider that the valve in the piston-head, called the *running-up valve*, can be controlled so as to bring the gun quietly to a standstill after running up without the use of a check buffer.

The Schneider-Canet running-up gear consists of a piston attached to the gun and working in the second of the above mentioned cylinders, which is filled with glycerine. On recoil the glycerine is forced into the air-reservoir, further compressing the air therein, which is already at a pressure of 225 lbs. per square inch. On completion of recoil the air-pressure forces the glycerine back into the running-up cylinder, behind the piston, propelling the gun forward to the firing position.

The intention is that the compressed air shall always be confined to its own reservoir, and shall never pass into the running-up cylinder, or have an opportunity of escaping through the packing of the gland. It is probable that this ideal state of things is not completely attained, but that a good deal of froth gets into the cylinder. However this may be, the gear in question has proved a practical success, and no serious trouble from leakage has been experienced.

Elevating Gear.

The Chinese or telescopic screw is now used by almost all makers. The long range required by a modern field gun entails a great length of screw, which is most conveniently obtained by making it telescopic.

The Krupp Super-Elevation Gear.

The ordinary forms of elevating gear are fully described in the official text-books. But the Krupp gear introduces a new principle important in the design of Q.F. guns. It is desirable in the interests of steadiness to get the gun as low as possible on the carriage; but the lower the gun the greater the difficulty in getting room for it to recoil at full elevation without fouling the trail. Now, in most equipments the cradle slides, upon which the gun recoils, are parallel to the axis of the gun. But it is not necessary that this should be so. It is possible to mount the gun so that its axis is permanently elevated as much as ten degrees above the line of recoil. A similar principle was embodied in our old coast-defence mountings, where the gun recoiled up a slide inclined at 4° to the horizontal. This super-elevation enables a high angle of elevation to be obtained with a low carriage.

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Super-elevation considerably complicates the stresses on the carriage. It increases the friction of the slides, and introduces a downward component of the force of recoil which has to be resisted by the axletree and by the elevating gear. Probably 5 degrees of super-elevation is as much as it would be desirable to give in a field gun. But in howitzers and in mountain guns this figure may be exceeded. A good instance of the application of this principle is illustrated in the chapter on Q.F. Mountain Equipments.

In the Krupp equipments in which a *sleigh* or sliding bed is interposed between the gun and the cradle the gear can be so arranged that super-elevation can be given only when required for high elevations, by raising the muzzle of the gun above the sleigh.

The Krupp principle is especially valuable in mountain howitzers, where the difficulty is to find room for recoil at 45° of elevation, with a very low carriage, without the breech striking the ground.

Effect of Super-Elevation on Steadiness.

It is claimed for the super-elevation system that it allows increased room for the gun to recoil at high elevations without striking the ground, and that it causes a downward pressure on the carriage which assists to keep the wheels on the ground.

We will briefly investigate the truth of the latter assertion.

Take the case of a gun fitted with super-elevation gear so that the axis of the gun makes an angle of 10° with the cradle guides, and suppose the gun fired with the axis horizontal. Then the gun will recoil up the guides. Let the actual recoil-velocity be 30fs.; then the gun will acquire a vertical velocity of 30sin 10° fs. or 5fs., and a horizontal velocity of 30 cos 10°fs.. This upward velocity of 5fs. is balanced by a corresponding downward stress on the carriage, tending to keep the wheels on the ground.

Now the gun attains its full recoil-velocity after about 1½ inches of recoil, or say 1/240 second; therefore the 5fs. of upward velocity is imparted to it in 1/240 second and the downward stress upon the carriage lasts only for the same time. This practically amounts to a downward blow upon the carriage, followed by a rebound from the earth. Suppose the weight of recoiling parts 10 cwt. and weight on wheels 20 cwt., then if the ground be supposed hard and the axletree perfectly elastic, the upward velocity of 5 fs. imparted to the gun will be converted on rebound into an upward velocity of $5\sqrt{2}$ or 3.5 fs. imparted to the gun and carriage.

That is, under the above conditions super-elevation will be prejudicial to steadiness.

For this reason, in the Krupp equipments, we find that the super-elevation gear is not fixed, but is so arranged that it can be applied only when required. It is intended to be used only at high elevations, when the line of recoil falls within the base formed by the spade and wheels, and the question of steadiness does not arise.

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Curved Recoil.

Suppose that the cradle guides instead of being straight are curved so that, starting with the axis of the gun horizontal, at the end of recoil the breech of the gun will be pointing 10° upwards. This construction possesses the advantages of super-elevation in that it allows increased space for the gun to recoil at high elevations without striking the trail or the ground. And further, it assists the steadiness of the carriage at low elevations. For if the curve be struck from a point above and slightly in rear of the centre of gravity of the recoiling parts, then the first motion of the gun on recoil will be slightly downwards, and the upward velocity will subsequently be gradually communicated to the gun during recoil. That is, instead of a downward blow upon the carriage followed by a rebound, we shall have a steady downward pressure on the carriage throughout the whole length of recoil.

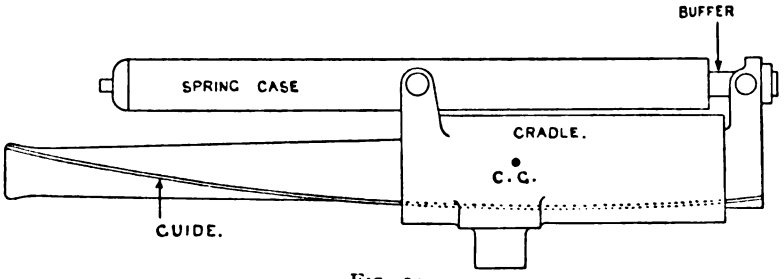

FIG. 34.

The calculation of the correct curve of the guides for maximum stability of the carriage under given conditions is a complex one. But it is not necessary to enter upon this, since in practice the curve of the guides must be a portion of a circle. Elliptical guides, for instance, would necessitate the gun being carried on two rollers, which entails a construction too elaborate for field artillery.

So far as the writer is aware, the system of recoil upon curved guides has not previously been proposed. Apart from manufacturing difficulties, the objections to it are apparent. The buffer-cylinder and buffer-rod must have pivoted attachments; and if the sights be connected to the cradle, then, unless the gun returns exactly to the same point on the curved guides after each round, errors of elevation will result. The idea is now put forward because it is becoming manifest that the power obtainable from an equipment of given weight, with straight recoil, has about reached its limit. And since the cry is still for more power and less weight, it is important to investigate any theoretical construction which promises higher efficiency.

In the Q.F. mountain howitzer especially it is exceedingly difficult to get room for a straight recoil of sufficient length to steady the carriage. It is possible that recoil upon curved guides may enable the difficulty to be overcome.

Lateral Traverse.

It is necessary to provide a means of traversing the gun sideways without moving the trail. For the spade, after a few rounds, buries itself so that it cannot be moved sideways without running up the gun and lifting the spade out of its hole.

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Page 47.—The later Ehrhardt guns are not pivoted on the axle-tree. See page 256.

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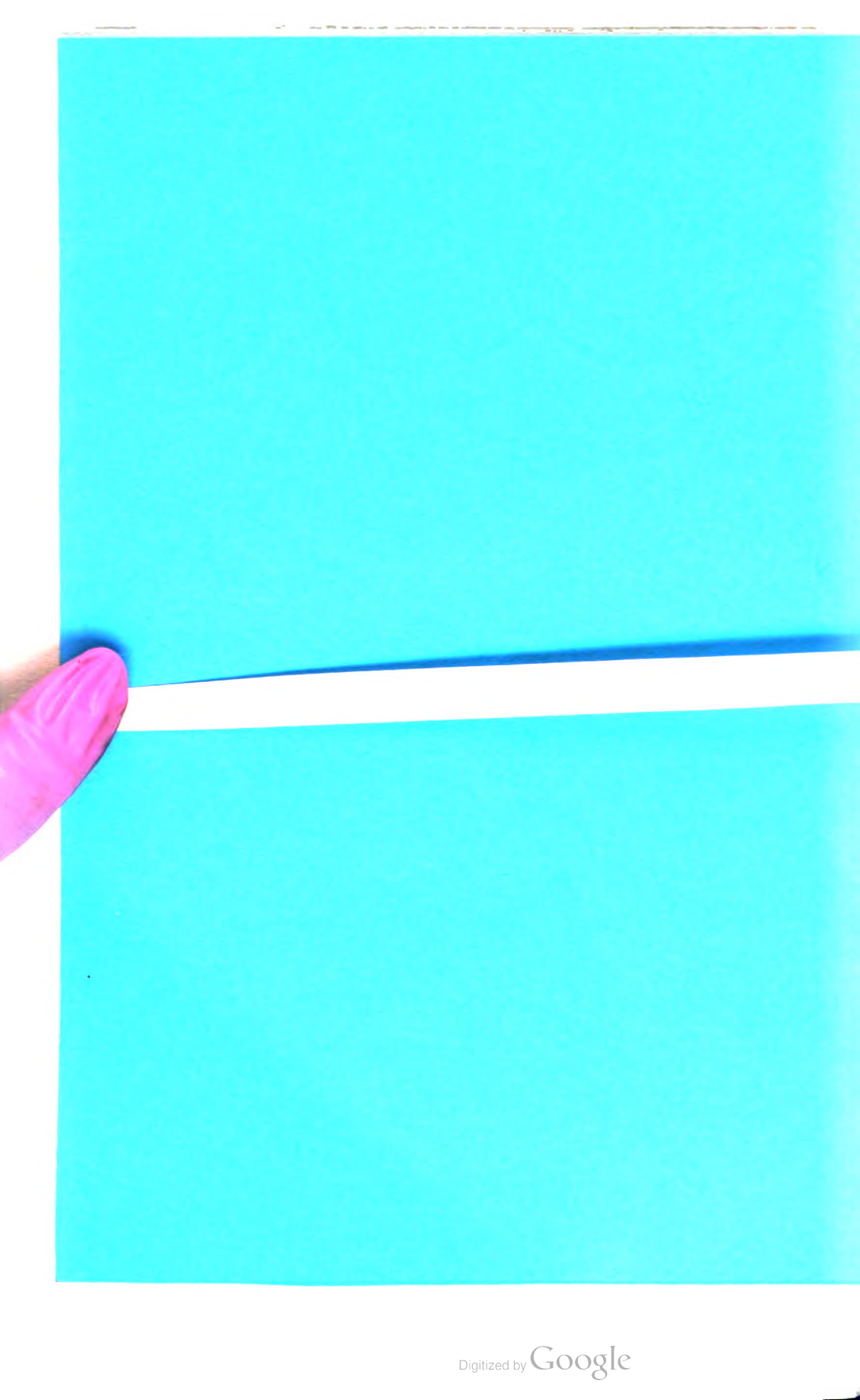

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Traversing may be effected in several ways. In the original French equipment the wheels are held fast by brake-shoes of peculiar construction. On coming into action the trail is raised and the blocks dropped to their lowest position, so that when the trail is lowered the blocks come *under* the wheels, forming dragshoes. These dragshoes have each a longitudinal rib or fin upon the ground surface, which sinks into the ground and anchors the wheels from moving sideways. To traverse the gun, the whole trail and cradle is made to slide sideways upon the axle, the point of the trail remaining fixed in the ground.

This system ensures the direction of recoil being always in line with the centre of the spade, so that the gun has no tendency to shift laterally on firing. On the other hand, the whole weight of the gun and trail has to be moved along the axletree, causing great friction and possible jams. Moreover a large hole must be cut in the shield to allow the gun to traverse.

Another and more common method is to mount the gun and elevating gear upon a top carriage, and to pivot this top carriage over the axletree. This makes the gun easy to traverse, and gets over the difficulty about the shield. But, when there is any traverse on, the gun now recoils at an angle to the trail, so that each successive round tends to shift the wheels and to force the gun further and further out of the line of fire, till extreme traverse is reached, and the trail has to be lifted and dropped in a fresh place.

A third method is to traverse the gun and cradle about a vertical pivot set in a saddle, which itself pivots on horizontal trunnions between the trail brackets. The saddle is extended to the rear to form the traversing bed, which is supported upon the head of the elevating screw. This method is adopted in the German equipment.

In the Ehrhardt equipment the saddle is dispensed with, and the vertical pivot of the cradle is set in a socket in the axletree itself, so that the axletree has to turn when the gun is elevated. The traversing bed is separate, and is attached by stays to the axletree arms.

The Spade.

The question of the best form of spade is still unsettled. Owing to the greater smoothness of recoil of the latest pattern Q.F. guns, due to improved boring of buffers, the tendency has been to reduce the size of the spade. The Krupp form of spade, with a horizontal plate in addition to the vertical one, as in the new German gun, is the most favoured on the Continent, as this form does not tend to bury itself. On certain natures of ground, however, this form grips badly, as the pile of loose earth which forms under the horizontal plate tends to lift the spade out of the ground.

Generally speaking, it may be laid down that to hold well in all natures of ground the spade must be both deep and wide.

The greater the depth of the spade, the greater the difficulty in getting sufficient elevation for the first round, before the spade has buried itself. This is especially the case on a forward slope. The

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point or long downward projection of the spade has, therefore, been reduced to the smallest dimensions, as at "A," and is sometimes duplicated as at "B." (Fig. 34.)

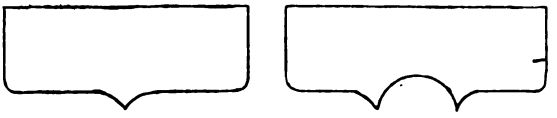

FIG. 35.

DIAGRAM OF STEADINESS.*

Let the conditions be as follows—

Length of trail measured horizontally from centre of axletree to centre of spade	100 inches
Height of centre of gravity of recoiling parts above centre of spade	40 inches
Weight of gun and recoiling parts	10 cwt.
Weight of carriage on wheels	10 cwt.
Ditto on spade...	1 cwt.

Axis of gun, horizontal.

For simplicity, suppose that in the firing position the centre of gravity of the gun and recoiling parts is exactly over the axle; then if the gun be shifted forward 10 inches it will balance the spade, and the whole weight, 21 cwt., will be balanced on the wheels. Then the distance from C.G. of gun and recoiling parts to spade will be 110″ horizontally.

Also suppose that the gun can be shifted back to a distance of 100 inches beyond the spade; then this will balance the weight on the wheels and the whole weight will be on the spade. The distance between these two extreme positions of the gun will then be 210 inches.

We can now draw the diagram.

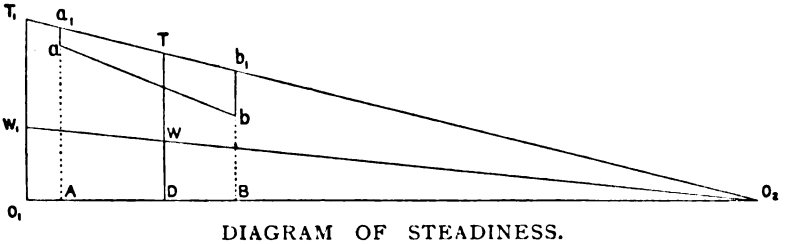

DIAGRAM OF STEADINESS.

Draw O_1O_2 representing 210″, and O_1W_1 upwards representing 21 cwt.

Then in the position O_1 the whole weight, 21 cwt., will be on the wheels; in the position O_2 the whole weight will be on the spade, and that on the wheels will be nil.

* I am indebted for this diagram to Professor Greenhill o the Ordnance College.

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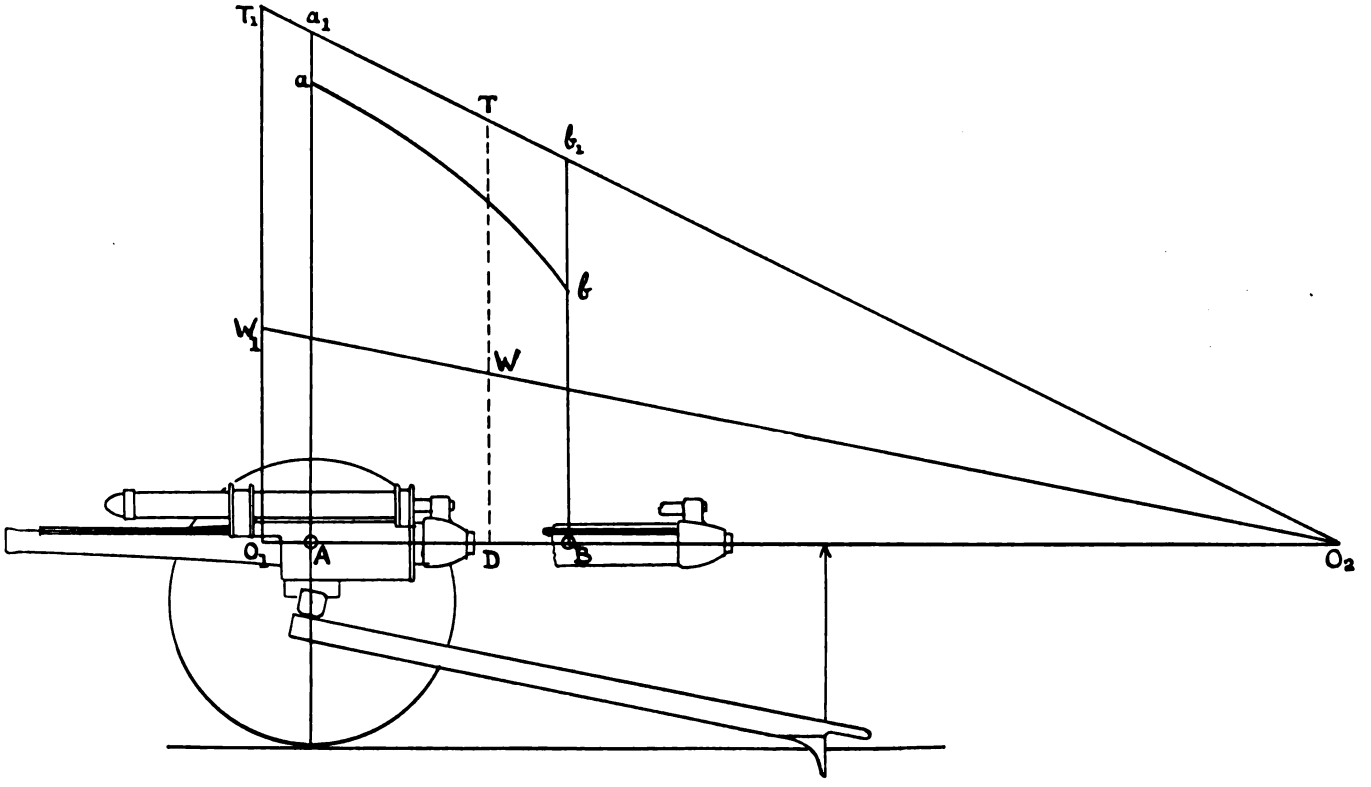

DIAGRAM OF STEADINESS.

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Join W_1O_2. Then at any point of recoil, if the C.G. of gun and recoiling parts be say at D, the weight on wheels will be DW.

Now on firing, the weight of gun and the weight on wheels, together 20 cwt., acts downwards at a distance from the centre of the spade of 100 inches, while the horizontal line in which the C.G. of the recoiling parts moves is 40 inches above the centre of the spade; therefore the weight which keeps the wheels down acts against the recoil which tends to lift the wheels at a mechanical advantage of 100 to 40.

Increase O_1W_1 to O_1T_1 in the ratio of 100 to 40, that is, make O_1T_1 represent 21 × 100/40 or 52.5 cwt., and join T_1O_2.

Then in any position of recoil D, TD represents the maximum pull on the carriage that will *not* lift the wheels from the ground.

Since the successive positions of T during recoil are all on the straight line T_1O_2, then, if the buffer-pull were the only resistance to recoil, the correct curve of buffer-resistance would be a portion of the straight line T_1O_2. If the length of recoil allowed be 50 inches, from A to B, then the curve of buffer-resistance would be the straight line a_1b_1. But we have also to consider the compression of the springs. This should be sufficient, at any point of the run-up, to support the gun on a slope of about 1 in 2½, besides about 1 cwt. of surplus compression to overcome the buffer-resistance. Therefore the initial compression of the springs must be at least 5 cwt. The maximum compression at full recoil depends upon the length of the recoil as compared to the length of the spring-column, and cannot be stated in general terms. Take it at 13 cwt. Since this spring-resistance must be deducted from the total resistance to get the correct buffer-resistance, draw b_1b downwards equal to 13 cwt. and a_1a downwards equal to 5 cwt. Then ab represents the correct theoretical buffer-resistance during recoil; that is, the resistance which just fails to make the wheels lift from the ground.

As a matter of fact ab is not a straight line, since the resistance of the spring does not increase in direct proportion to its linear compression, but in a higher ratio. But for practical purposes ab may be taken as correct in getting out an experimental design, subject to a correction for air-spacing which is required in order to allow free recoil till the shell has left the bore, and to a reduction of about 20% in order to give a surplus of steadiness under unfavourable conditions such as bad or sloping ground.

In the actual construction of a buffer intended to give a certain graduated resistance the depth of the buffer-ports is worked out from empirical data and corrected by the buffer-gauge described in Chap. I.

Running-Up Pressures.

During running-up the springs exert a backward pressure on the rear plate of the cradle, tending to press the spade into the ground, and a forward pressure on the buffer-cylinder. The latter is communicated through the buffer-piston to the front of the cradle and so to the carriage, and tends to lift the spade out of the ground. So long as the gun and buffer continue to give way to this latter pressure, and to move forward, the parts are not in a condition of static

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equilibrium, so that it is less than the pressure on the base-plate of the cradle, and there is no tendency to shift the carriage forward or to lift the spade. But if the buffer-resistance is insufficient to bring the gun to rest in the firing position, the gun runs up against the stops at the front of the cradle, producing a dynamic jerk which may be sufficient to lift the spade. If the gun when it strikes the stops has still a forward velocity of 5fs., then if (as assumed) the weight of the gun and recoiling parts is 10 cwt. as against 11 cwt. for the lower carriage, then the effect of the impact will be to impart a momentary velocity of nearly 5 fs. to the carriage till again checked by the springs; while the gun rebounds from the stops and comes to rest. If the carriage be prevented from moving forward by the wheel-brakes, then it will tend to overturn forwards, lifting the spade out of the ground.

It is therefore necessary that the buffer-resistance to running-up should be sufficient to absorb all (or nearly all) of the work done by the springs.

In the figure the work of the buffer-resistance is denoted by the area AB*ab*, and the work done by the springs by the area aba_1b_1. It will be seen that in the case of a gun the latter is much less than the former. But in the case of a howitzer powerful springs have to be used to lift it at 45° elevation, and it may be necessary to increase the buffer-resistance in running up at low angles of elevation, as by the use of the Vavasseur gear, to prevent the carriage from overturning.

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CHAPTER VII.

THE SHIELD.

The introduction of the Q.F. gun and of the long range magazine rifle have so increased the volume of fire to which a field gun is exposed in action as to render it imperative to provide cover for the detachment. This requirement has been met by the gun shield.

Prior to the introduction of guns recoiling on the carriage, several attempts were made to provide shields for the detachments. It was however found impracticable, within permissible limits of weight, to fix a shield to a recoiling carriage, as either the shield itself or its attachments broke up on recoil. Moreover, the shield was of little use for protection, since the gunners had to step clear of it on firing. With the introduction of the Q.F. equipment this difficulty disappeared, and the size and thickness of the shield are limited only by its weight. Every ounce of weight in a well designed equipment has to serve a useful purpose, and it is the business of the designer to distribute the weight to the best advantage between defensive armour and offensive power.

The best distribution of weight is not easy to arrive at. It is possible to equip a gun with a shield which will keep out both infantry and shrapnel bullets at the shortest ranges. Such a shield with its attachments, 56″ high and 5′ wide, weighs about 2 cwt. Its thickness would be about 6 mm., or nearly ¼″.

The Swiss have adopted a shield 4¼ mm. or 0.167″ thick; the German shield is said to be 4 mm. or 0.1575″ thick; while the new American shield is 5 mm. or 0.2″ thick.

The 5 mm. thickness keeps out the Mauser or Mannlicher bullet absolutely at 200 yds. and stops a great many bullets at shorter ranges. This thickness of shield weighs 8.57 lbs per square foot, and so allows of fairly extensive protection without undue increase of weight.

The height of the shield depends in some measure on the method of ammunition supply. If the wagon is to be behind the gun, the shield should be 6′ high, to give cover to men bringing up ammunition from the rear; if the wagon is to be close alongside the gun, the shield need not be more than 5′ high, which is sufficient to protect men kneeling behind it.

The shield is set as far back as possiple, and the upper portion is sloped back to give additional protection. Our own shield is in two portions, the lower portion folding up for travelling. The German shield has in addition a top flap, which is kept down (for the sake of invisibility) till the gun is actually under fire, and is then raised, giving a total height of 5½ feet.

A flat square gun shield makes a conspicuous target and must be painted a dull colour and mottled or clouded to reduce its visibility.

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Even so it is apt to show up when it catches the light. It will probably be found necessary to break the flat surface of the front of the shield by carrying small stores on it.

Covering the front of the shield with sheepskin with the wool on makes it less conspicuous. At Spion Kop the Boers covered the shields of their poms-poms with sacks to prevent us from locating them.

Shields are usually made of hard nickel or nickel-chrome steel. Messrs. Ehrhardt use steel with a tensile strength of 105 tons per square inch.

THE WAGON SHIELD.

Since the normal method of coming into action is "wagon supply," with the wagon and limber, or wagon body, close beside the gun, the wagon shield is no less important than the gun shield; for in a Q.F. equipment three men are employed in preparing and supplying ammunition, while only the same number, including the No. 1, are employed in the service of the gun.

In the French equipment, in which the wagon body is up-ended alongside the gun, the bottom of the wagon body is armoured and the bullet-proof doors open outwards, giving a wide protected area. In equipments in which the wagon and limber are placed alongside the gun, the wagon body opens to the rear and the door hangs down to the ground, so that men kneeling behind the wagon are completely protected.

Shell versus Shield.

A high-explosive shell which strikes a gun-shield explodes in the act of passing through, tearing a large hole in the shield and damaging the vulnerable parts of the gun and carriage. The effect of the splinters is not only to kill every man at the gun but also the men at the wagon alongside. As against the H.E. shell, then, the shield does not contribute to the safety of the detachment but decidedly the reverse. It has therefore been proposed to make the shield hinged so that it can be folded up when desired. An example of this construction is shown in Fig. 36, which represents one of Messrs. Ehrhardt's designs. Side shields are sometimes added, as in Fig. 35, both to protect the detachment from diagonal fire and to limit the effects of the burst of a shell. Both hinged shields and side shields have many advantages, the principal objection being the increase of weight.

When attacked by percussion shrapnel the disadvantages of the shield are less marked. It was formerly supposed that a percussion shrapnel striking the shield would pass through it and would not burst till it had travelled five or six yards past the gun. But recent experiments with more sensitive T. and P. fuzes have shown that a shrapnel can be made to burst as it passes through the shield and that the spread of the bullets is sufficient to cause considerable damage behind the shield, (see chapter IX.) Against percussion shell of both kinds, therefore, the protection afforded by the shield may be considered to be a negative quantity; but this disadvantage is far outweighed by the practically complete protection of the detachment both against rifle bullets and time shrapnel.

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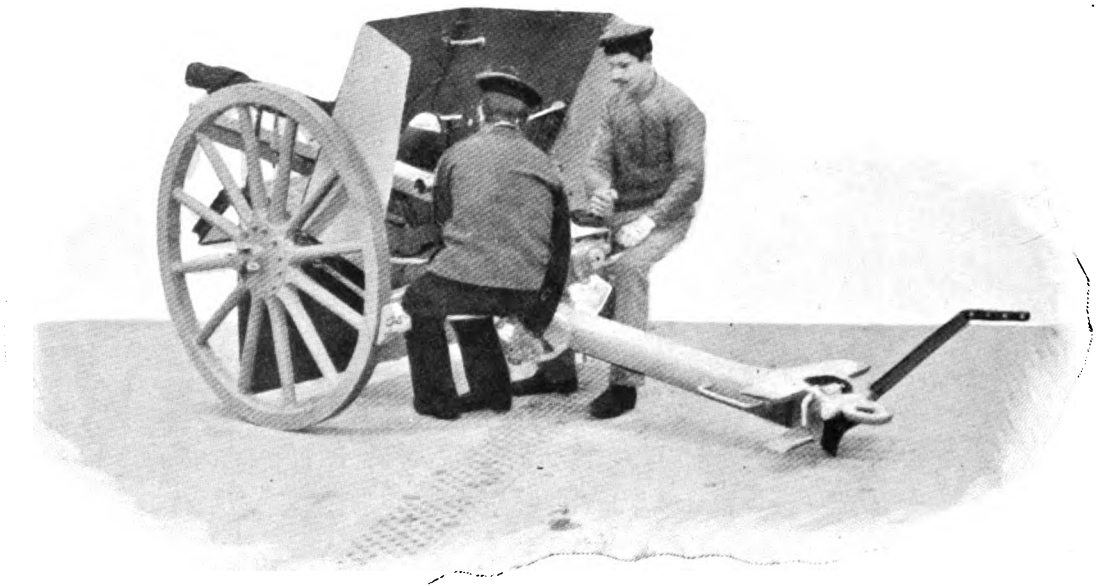

EHRHARDT SHIELDED GUN.

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Bullets versus Shield.

The ordinary infantry bullet at 400 yards is powerless to pierce a 3½ mm. gun shield, and the shrapnel bullet, which at service ranges has a much lower velocity than the rifle bullet, is stopped by an even less thickness of steel; but when special armour-piercing rifle or shrapnel bullets are used the case is altered.

A steel rifle bullet, or even a leaden rifle bullet with a steel tip, will penetrate a ¼" shield at very short ranges, and a steel shrapnel bullet, if the shell be burst close up, will penetrate a 3 mm. (0.118") shield at medium ranges.

Thus Messrs. Krupp in 1902 succeeded in getting 10-gramme steel bullets (45 to the pound) through a 3 mm. shield at 3500 metres. Only a small proportion of bullets penetrated and these were probably from shell burst close up to the shield. On the other hand Messrs. Ehrhardt found that a 4 mm. shield (0.157") kept out the steel bullets even at short ranges.

Since 1902, shields have been improved, the metal now used being hard nickel steel or nickel-chrome steel. Shields of this material 3½ mm. (0.14") thick are now relied on to keep out steel shrapnel bullets at all ranges. This being so, there would appear to be no object in adopting steel shrapnel bullets unless one's opponent were known to be equipped with gun shields of less than this thickness; and even then the use of steel bullets would entail a loss of efficiency against infantry, for the steel bullets, being less dense than the ordinary mixed metal bullets in the proportion of 8 to 9, do not carry so far and are less effective against troops in the open; and, to add to these disadvantages, the larger size of the steel bullets sensibly reduces the number that can be packed in a shell.

Thus Messrs. Krupp found that their field shrapnel which normally held 300 mixed metal bullets of 11 grammes (41 to the pound) would only hold 265 steel bullets of 10 grammes (45 to the pound).

The Austrians are experimenting with a steel bullet weighted with a lead mantle which extends over the base and body of the bullet as far as the shoulder. This again is covered with a nickel-silver envelope extending from the point to the base of the bullet. The idea is that on impact upon a shield the steel core will pass through it, leaving the lead mantle behind.

The French D bullet is long and slender, with an elongated point; it is of solid gun-metal. The German S bullet is of similar form, but of lead and nickel silver. Both of these bullets give improved penetration, but neither of them is a match for a 5 mm. shield.

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CHAPTER VIII.

CONTROLLED RECOIL.

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When hydraulic buffers were first introduced for field guns the resistance to recoil was regulated by varying the bore of the buffer at different points. This method did not answer, as the unsupported piston-rod tended to strain the gland, causing leakage. The next step was to make the piston a close fit, obtaining the necessary windage for the passage of the oil or glycerine by forming channels of varying depth (called ports) in the inner surface of the buffer-cylinder. This method is used in our own Q.F. equipment.

Higher efficiency, due to more perfect control, is obtained by the use of the Vavasseur duplex valve, as modified by Messrs. Ehrhardt, Krupp, and Vickers Maxim.

The Vavasseur valve is shewn diagrammatically in the accompanying figures.

Fig. 1.

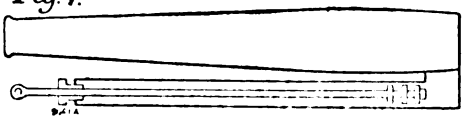


Fig. 2.

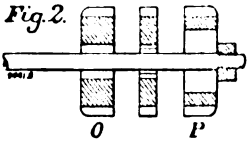
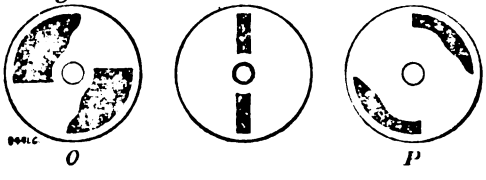


Fig. 3.



The recoil gear, Fig. 1, is of the type in which the buffer is fixed to the gun and recoils with it, while the piston-rod is attached to the cradle, and does not recoil.

The piston, Fig. 2, is divided into two parts, O and P, with a loose disc-valve between them. During recoil and during running up the glycerine in the buffer has to pass through ports in these three pieces.

The disc-valve is free to traverse from right to left, and free to revolve upon the piston-rod. The latter motion is controlled by two projections upon its circumference which fit in to rifled grooves in the buffer, causing it to turn through (say) a quarter of a circle during recoil and to turn back again through the same angle while the gun is running up.

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Now in a field gun it is desirable that the buffer resistance should diminish during recoil, as the centre of gravity of the gun and carriage shifts to the rear, and the stability diminishes. A further reduction of resistance has to be made to allow for the increased resistance of the running-up springs as they approach full compression. Towards the end of recoil the resistance has to be increased again to bring the gun gently to a stand-still. This graduated resistance is obtained by the shape of the ports in the piston-head P, Fig. 3.

As the gun recoils the glycerine in the cylinder has to force its way past the piston from front to rear. The disc-valve immediately closes against the face P, so that the only passage left is the area of the curved ports in P exposed by the straight ports in the disc-valve. As the latter revolves this area first increases and finally diminishes to nothing, bringing the gun to a standstill.

The resistance during running-up should at first be as low as possible in order to relieve the running-up springs of all unnecessary work, and to enable them to be kept as light and slender as possible. For thick heavy springs will not stand compression beyond about 50 per cent of their length without injury. As the gun approaches its original position the resistance has to be increased to bring the gun to rest without a jerk, which would lift the spade at the end of the trail out of the ground.

This is provided for by the ports shewn at O, Fig. 3. The disc-valve now closes tight against the face O, and the glycerine passes freely through the whole area of the ports in P, and through the whole radial width of the ports in O exposed by the straight ports in the disc-valve. As the width of the curved ports diminishes the resistance brings the gun smoothly to rest in the firing position.

In a field howitzer the problem to be solved is somewhat different. When fired at 45 degrees of elevation the howitzer can only recoil for a limited distance without striking the ground; while if fired at a low elevation with this short recoil the wheels would lift and the carriage would be unsteady. The buffer resistance has therefore to be automatically adjusted so as to vary the recoil according to the elevation.

This is effected by Messrs. Ehrhardt's invention. The piston-rod has a bevel wheel at its forward end, gearing into a toothed segment fixed to the carriage. The effect of this is to rotate the piston-rod and piston through a portion of a circle as the howitzer is elevated.

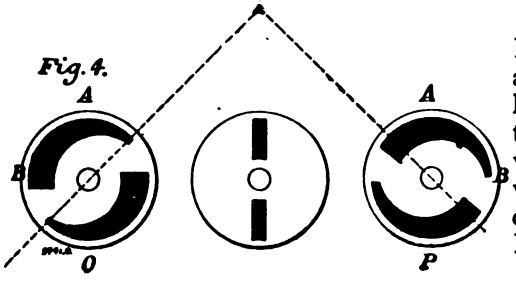

Fig. 4.

In Fig. 4 the piston-head P has been rotated through a quarter of a circle to the left. Then during recoil the port in the disc-valve will travel from A to B, and will expose a smaller area of the curved port than if P had not been rotated.

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Howitzer running-up springs have to be powerful in order to lift the weight of the howitzer, with the recoiling parts attached to it, at an angle of 45 degrees. If the howitzer were fired at a low elevation without any resistance to running-up, the strong springs would drive the howitzer forward so violently as to upset it on to its muzzle. Therefore the buffer-resistance to running-up must be automatically increased at low elevations and reduced at high ones.

Thus, in Fig. 4, O is the forward piston-head, rotated for 45 degrees of elevation. The ports of the central valve, in running up, travel from B to A, exposing a larger area of the curved port than if the piston had not been rotated.

Further and more complex variations of resistance may be arranged for by suitably shaping the ports of the central disc-valve, or by inclining then at an angle to its diameter.

Vickers Sons and Maxim have patented a valve-gear which is very similar in principle to the above, the chief difference being that the buffer instead of the piston is automatically rotated. Messrs. Krupp, in their field guns, use the front or running-up half only of the Vavasseur gear, the recoil being regulated by varying the depth of the ports in the walls of the buffer. French makers who prefer the compressed-air gear, which gives a nearly uniform pressure in running-up, use the rear or recoil half of the Vavasseur gear for their field howitzers. Messrs. Cockerill, of Seraing, prefer a channel outside the buffer, with a stop-cock which gradually closes as the howitzer is elevated.

Controlled recoil-gear is objected as adding an extra complication to the Q.F. field equipment. But it gives greater smoothness of action and therefore greater steadiness for the same weight, and this is equivalent to a reduction of weight, or else an increase in power, with the same degree of steadiness. And since in these days every ounce of weight must serve a useful purpose, there is no doubt that the principle of controlled recoil will be extensively applied in future field equipments.

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Page 57.—Nitro-guanidin is a new nitro powder with which finely-divided carbon is mechanically incorporated. It is claimed that it gives low temperatures in the bore.

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CHAPTER IX.

AMMUNITION.

We cannot here afford space to go into the details of ammunition manufacture. But the design of ammunition is at least as important as the design of the gun or carriage, and requires careful study.

Fixed Ammunition.

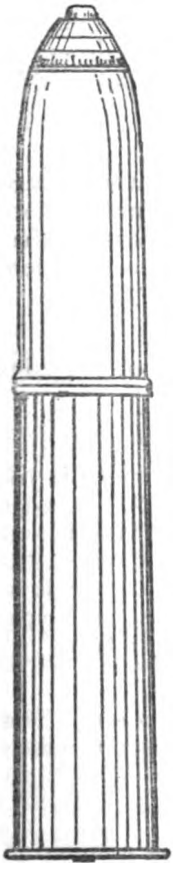

FIG. 39.

All modern field guns now use fixed ammunition, the powder being contained in a brass or bronze cartridge case similar to that of a rifle-cartridge. The shell, which is always carried fuzed, fits tightly into the front of this case.

The principal advantages of fixed ammunition are rapidity of handling, and the abolition of a separate friction tube and lanyard. Another important advantage is that no asbestos pad or obdurator is required on the breech-screw, since the metallic cartridge expands on discharge so as to prevent any escape of gas to the rear. Difficulties of packing have been overcome by the introduction of honeycomb ammunition boxes, opening to the rear, in which each round of ammunition fits into a separate tube. A removable clip on the base of the cartridge facilitates its withdrawal from the tube, and at the same time protects the cap from accidental blows.

The Powder.

Smokeless powder is of two principal types, called gun-cotton powder or nitro-glycerine powder, according as one or other of these ingredients predominates in its composition.

Generally speaking, nitro-glycerine powder is both more powerful and more uniform in action than gun-cotton powder. The principal objection to it is the very high temperature developed on explosion, which, when large charges are employed, is above the melting point of steel. For this reason its use materially shortens the life of heavy guns.

Gun-cotton powder is free from this disadvantage, but requires to be used in larger quantities, necessitating a larger powder chamber and corresponding increase of weight in gun.

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Cordite.

For the purposes of the English Army, which has to fight under extreme conditions of heat, cold, dryness, and moisture, the best powder is found to be a mixture of nitro-glycerine and gun-cotton. The composition of cordite is given in the Treatise on Ammunition as:

58 parts nitro-glycerine.
37 ,, gun-cotton.
5 ,, vaseline.

the last-named ingredient serving to render it waterproof and to increase its keeping qualities.

For heavy guns a new powder called "Cordite M.D." has lately been introduced; this contains a larger proportion of gun-cotton, namely, 30 parts nitro-glycerine, 65 gun-cotton, and 5 vaseline, and gives lower temperatures in the bore.

Ballistite.

This powder consists of equal parts of nitro-glycerine and gun-cotton, with some camphor added. It is more powerful than cordite, giving about 10 per cent. higher velocities. Its keeping qualities are however considered inferior to those of cordite, and it is not used in the English Army.

Tubular Powder.

Both cordite and ballistite are now frequently made in the form of tubes instead of cords. The internal diameter of a tube is more constant than the area of the interstices between the cords, so that the tubular form affords more regular ignition and more complete combustion of the powder.

Tape Powder.

As a substitute for tubular powder, tape powder, or powder consisting of strips of girder section, is sometimes used.

Continental Powders.

Germany, after trying a nitro-glycerine powder, has lately introduced gun-cotton powder. The French "Blanche Nouvelle" powder consists of gun-cotton, tannin, and saltpetre. It is more violent and gives a higher pressure in the powder chamber than other smokeless powders. Practically all the other nations use gun-cotton powders. These are variously made up in tubes, leaflets, tablets, or strips. The Italians use rolled-up sheets of a nitro-cellulose called *filite.*

Ammonia Powder.

These powders are safe, powerful, and regular in action. The only objection to them is that they absorb water from the air, which necessitates their being kept in air-tight cases.

Ammonal.

This powder has been recently introduced, and is now adopted in Austria as a burster for H.E. shells, its advantage lying in the fact that it can be effectively detonated without a fulminate primer. It consists of 70% ammonium nitrate, 25% metallic aluminium, and 5% charcoal. The makers claim that if pure nitrate is used the powder is non-hygroscopic.

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DETONATION.

Explosion may take place in two ways, by burning or by detonation. In the first case the flame from the exploding charge is quickly communicated to all the exposed surfaces of the cords or grains of powder, and each cord burns with a rapidity proportional to its exposed surface. In the second case, when the explosive substance *detonates*, the initial force of the explosion is sufficient to break down the structure of the cords, etc., of powder so that the flame is not only communicated to the surfaces exposed but reaches every particle of the mass. This instantaneous ignition is called *detonation*.

Some substances are more easily detonated than others, the most sensitive ones being known as fulminates.

Detonating substances are useless as propellants, since the force is generated so rapidly as to expend itself on destroying substances in contact with it instead of projecting them to a distance. In the same way, it will be found difficult, for instance, to close an open door by a sudden blow. A violent kick might break a panel and yet hardly move the door, while a steady push with the finger would close it at once.

Partial Detonation.

When a high-explosive substance is ignited (not detonated) in a closed vessel, then it may happen that before the walls of the vessel give way the pressure rises high enough to break down the structure of the still unburnt portion of the explosive, and cause it to detonate. This frequently happens with a H.E. shell with a weak detonator or weak primer.

Similarly, when large masses of gun-cotton, cordite, etc., are burnt unconfined, the temperature and pressure may rise high enough in the interior of the pile to produce partial detonation.

Action of Smokeless Powder.

All smokeless powders are of gelatinous or horny structure. The object of this is to prevent the instantaneous penetration of the burning gases to every particle of the powder, and so to allow the powder to burn steadily instead of detonating. All smokeless powders are liable to detonate if sufficient violence be used; thus, if a gun-cotton primer and detonator, as used for demolitions, were inserted into a cordite charge before firing, the effect would probably be to destroy the gun. Even a strong fulminate percussion cap is sufficient to produce partial detonation and excessive pressure in the powder chamber. When smokeless sporting powders were first introduced, owners of high-priced breech-loaders occasionally discovered this to their cost. Accordingly with smokeless cartridges a cap consisting of chlorate of potash, sulphide of antimony, and ground glass is used. With the service ammunition detonation of the charge in the bore is considered to be impossible.

Sizes of Smokeless Powder.

The more finely the powder is subdivided the more rapidly is the flash promulgated through the cartridge. Powder is accordingly made up in leaves, grains, cubes, cords, or (more recently) tubes, and

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the size of the cords, &c., is regulated so as to provide as far as possible for the combustion of the whole of the powder before the shell leaves the muzzle, without giving rise to an unduly high pressure in the powder chamber. The description of cordite used in field guns is known as "size 5."

Primers.

Smokeless powder is difficult to explode in a cartridge without the use of a primer to convey the flash from the cap. Formerly black powder was used for this, giving a considerable amount of smoke at the muzzle. Primers of specially manufactured smokeless powder are now used, as primers of ordinary E.C. or Schultz were found to give high and irregular pressures. Krupp uses "powder-cloth," or cloth woven from gun-cotton yarn.

Effect of Temperature on Ballistics.

It has been found by experiment that in field guns each degree of temperature of the charge above or below 80° F. makes a difference of plus or minus 2.5 fs. in muzzle velocity. At practice for range and accuracy, from which range tables are compiled, the cordite cartridges are kept at a uniform temperature of 60° F. Thus, if the M.V. of a gun be given in the Range Table as 1580 fs., then with the thermometer at 75° the M.V. should be $1580 + 15 \times 2.5 = 1618$ fs. and, with the thermometer at 35°, $1580 - 25 \times 2.5 = 1517$ fs.

Therefore fuzes will tend to burn long on a hot day. This may be kept in mind by the alliterative line—

"Shorten your shrapnel fuze in sweltering summer."

Keeping Qualities of Cordite.

Cordite is found to deteriorate or partially decompose when exposed for long to temperatures above 125° F. Under very trying conditions, as on service in India, ammunition boxes should therefore be protected with blankets. The temperature in cordite magazines should not exceed 100° F. When cordite is frozen, the nitro-glycerine is apt to sweat out, and the cordite is then dangerous to handle. The nitro-glycerine will be re-absorbed when the temperature rises to 45°.

Cordite is unaffected by damp, and cartridges may be safely fired after immersion in water.

Lyddite.

For convenience, lyddite may be considered under the heading of powder.

It is the Service burster for high-explosive shell, and is stated in the Treatise on Ammunition to consist of picric acid, melted and poured into the shell, where it solidifies. It is then a yellow mass of about the consistence of roll sulphur. Picric acid is one of the safest of known explosives, having been used in manufacture for many years before its explosive qualities were discovered. It requires a primer of dry gun-cotton or picric powder (ammonium picrate) to detonate it.

Picric acid is used in England and Japan as a burster for H.E. shell. The French Melinite and the Japanese Shimosé are practically the same as lyddite.

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The use of picric acid as a burster for small and medium-calibre shells has been abandoned by all nations except ourselves and the Japanese. Except in calibres above the 6-inch it is very difficult to secure complete detonation without the use of a fulminate primer, which is considered too dangerous for use in our service. The Japanese base fuze used with Shimosé contains no less than 60 grains of fulminate composition, but it is believed that many serious accidents have resulted from its use.

The results obtained from our 5" howitzer lyddite shell (cast iron) in S. Africa are thus described—

"Usually the effect of the burst is to produce a small crater from which the green and yellow fumes of burning lyddite arise. Frequently the shell breaks across, the front half being found in the hole; the bulk of the fragments are found lying within a radius of 20 yards."

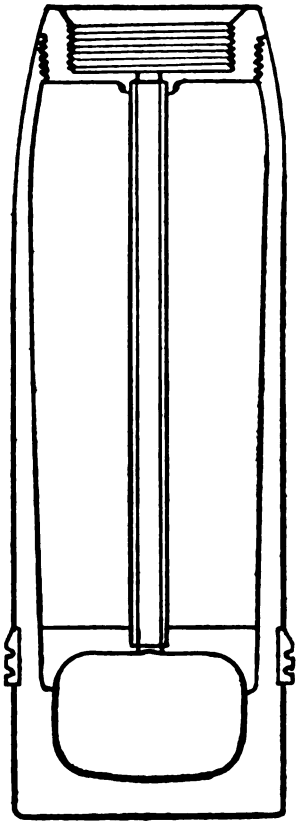

FIG. 40

EHRHARDT 75mm. SHRAPNEL, 1904 Pattern.

This shrapnel weighs 14.3 lbs. fuzed with aluminium fuze, and contains 306 mixed metal bullets of 42 to the pound, pressed in. The driving charge consists of 3 oz. of fine grain black powder, and the central tube is filled with pellets of compressed powder. A smoke producing charge of 1¾ oz. coarse black powder is poured in among the bottom bullets.

Austria has adopted ammonal as a burster. This answers well in shells, since no difficulty then arises from its tendency to absorb moisture. Switzerland uses the same powder in the shell as is used in the gun. Other nations use specially manufactured nitro-powders. In some cases, as in the Krupp H.E. shell illustrated in Fig. 46, the difficulty of getting in the burster through the fuze-hole is avoided by inserting it from the base of the shell.

THE SHELL.

Field Artillery projectiles are either shrapnel or high-explosive shell. Common shell and case-shot may now be considered as obsolete.

Shrapnel.

The annexed figure gives a section of a modern shrapnel without the bullets. The action and general construction of a shrapnel shell being well known, it is only necessary to describe the peculiarities of this particular design which affect the shooting.

In the first place, the shrapnel body is intended not to break up on explosion, but to act as a short gun and to propel the bullets forward with the maximum attainable velocity. For this purpose the shell has a large powder chamber, intended to contain

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a driving charge of 3 oz. of fine-grained black powder. Messrs. Ehrhardt, the makers of this particular shell, have found by experiment that the driving-charge gives an increased velocity of 350 fs. to some at least of the bullets. But it is considered probable that the *average* extra velocity imparted to the bullets is not more than 200 fs., as most of them escape centrifugally before the full force of the charge is developed. (See Chapter on Shrapnel Fire.)

The walls of the shell are made as thin as possible, in order to get in the greatest possible weight of bullets. For this reason the shell is made of hard and tough nickel steel, pressed hot from the ingot and afterwards drawn out hot by passing through successive dies.

It will be observed that the body of the shell is contracted at the shoulder. The object of this "choke-boring" is to get a closer pattern with the bullets, the idea being that the outer ring of bullets get an inward impulse from the incurved shoulders of the shell which reduces their centrifugal velocity. The soundness of this theory has not been conclusively proved. This form of body, however, gives facilities for getting the greatest number of bullets into the shell, and the makers consider this a sufficient reason for adopting it.

The diaphragm separating the powder from the bullets is a steel drop-forging, and is flat instead of conical so as to give the minimum dispersive effect on the bullets. It is supported by a shoulder in the wall of the shell, into which it fits tightly. There is no tin cup to contain the burster, but the powder-chamber has a smooth internal coating of lacquer.

The curve of the head and shoulder of the shell is struck with a radius of 2.3 diameters, this shape of shell being found to keep up its velocity much better than one with a head of only 1½ diameters. The latest pattern of Russian shrapnel has a head struck with a radius of no less than 2.75 diameters, and the St. Chamond shell shewn in Fig. 40 have 3-diameter heads.

The principal objection to these extra long heads is the loss of bullet capacity which results from their use. It is estimated that a 15-pr. shell with 2-diameter head holds 8 more bullets (42 to the lb.) than a shell of the same total weight with head struck with 3-diameter radius.

A smoke-producing charge of 1¾ oz. of coarse black powder is poured in among the bottom bullets, and the bullets are consolidated by pressure, a dead-weight pressure of 10 tons being applied three times during the filling of the shell. The object of this is first to prevent prematures, due to the grinding of the smoke-producer between the bullets on discharge, by consolidating the bullets so that they cannot move; and in the second place, to get the maximum number of bullets into the shell.

The bullets are further secured by pouring melted rosin into the interstices.

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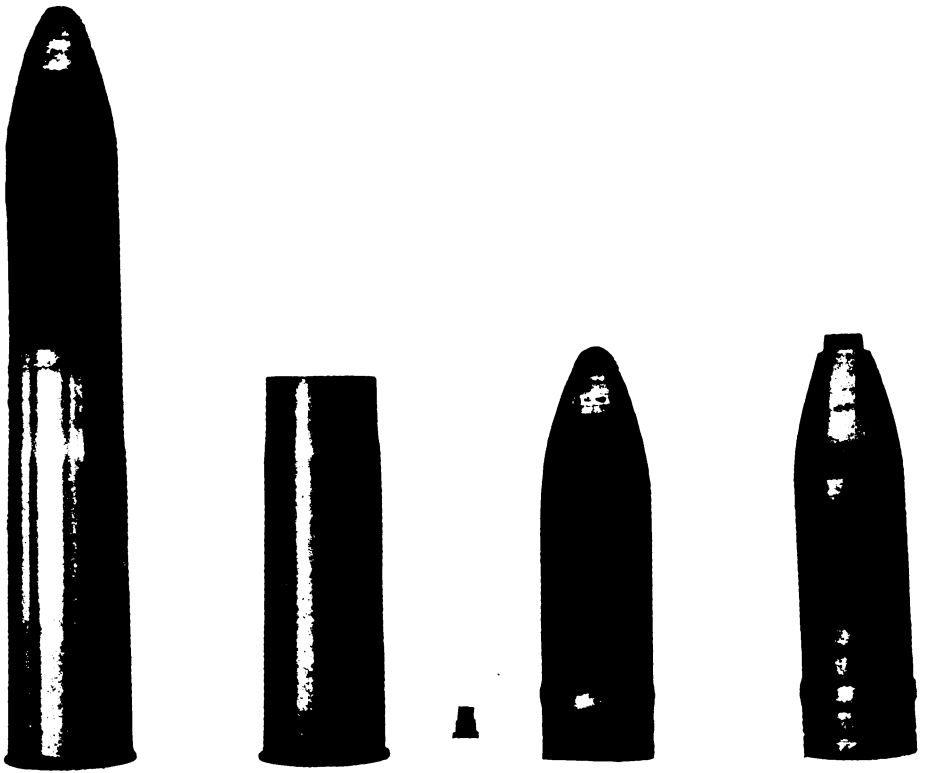

ST. CHAMOND Q. F. AMMUNITION.

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Another form of field shrapnel, specially devised to contain a large proportion of bullets and to give a regular dispersion of the bullets, is the Darmancier shrapnel shewn in Fig. 42. It will be noted that the diaphragm and central tube are in one piece, so as to prevent the powder-gases from penetrating among the bullets and scattering them irregularly. The bullets are flattened so as to have a firm regular bearing upon each other. These shrapnel have given very good results.

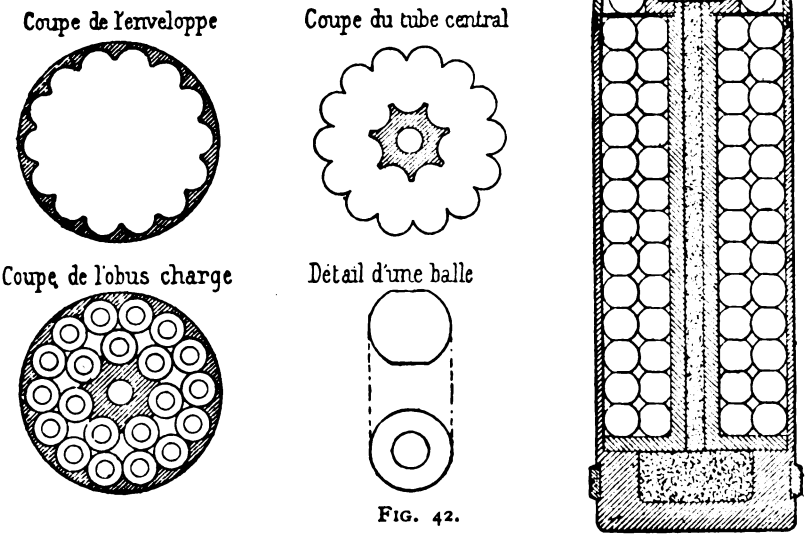

FIG. 42.

Proportion of Weight of Bullets to Weight of Shell.

In the above-mentioned Ehrhardt shrapnel, fuzed with an aluminium fuze, the weight of bullets is 51 per cent. of the weight of the shell. The Armstrong field shrapnel (1904) contains no less than 53 per cent. of bullets, but the powder chamber is smaller than in the Ehrhardt shell.

Taking the best size of bullet as 39 to the pound, this gives 300 bullets in a 14.5 lb. shell The same shell would hold 315 bullets of 41 to the pound, or 346 of 45 to the pound.

Cordite Shrapnel.

On inspecting the illustration already given of a field shrapnel, it will be noticed that a large proportion of the available space is taken up by the driving charge of 3oz. black powder. Now since smokeless powder occupies a much smaller space than an equivalent charge of black powder, it would appear desirable to use cordite or ballistite in the powder chamber of a shrapnel shell. If the powder chamber could be cut down to half its height a considerable saving in weight would be effected, which could be utilized in providing an increased number of bullets. The smoke-producer would then occupy the interstices between the bullets, so that no space would be wasted.

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Several attempts have been made to realise this ideal, but the results have not so far been encouraging. The trouble is that the smokeless powder, when closely confined in a chamber at the bottom of a shell, detonates or partly detonates instead of burning quietly. The effect is occasionally to blow off the base of the shell, but usually to break up the shell violently, scattering the bullets in all directions.

The idea is however perfectly sound in theory, and only awaits the introduction of an explosive powerful in proportion to its bulk and warranted not to detonate, to become a practical fact.

In the Krupp high-explosive shrapnel (Fig. 46) the driving charge, to save space, is in the form of a pellet of compressed black powder behind the diaphragm. But experience with compressed-powder bursters is so far wanting.

Smoke Composition.

All modern shrapnel contain smoke composition to make the burst more visible. This is also important for another reason. The rapid fire of a Q.F. battery with smoke-producing shrapnel makes a dense cloud of smoke in front of the enemy's line, which, on a moderately still day, is sufficient to prevent him from taking effective aim.

Thus we read that at the battle of Liao-Yang, on the 30th August, 1904, the Japanese artillery positions were enveloped in dense clouds of smoke, caused by the continuous explosion of the Russian shells, which prevented the Japanese gunners from taking aim.

Various smoke compositions are used, but the simplest and probably the best is coarse black powder, of which about two ounces is poured among the bottom bullets before the hot resin which fixes them is introduced. These shell at first gave rise to prematures, owing to the grinding together of the bullets on discharge. This has now been overcome by consolidating the bullets by pressure. This method has also the advantage of increasing by about 10% the number of bullets that can be packed into a shell.

Messrs. Ehrhardt have lately introduced a new form of smoke-producer. This consists of coarse-grain black powder which has been stirred up in melted resin, so that each grain is coated with resin. This is claimed to be perfectly safe from prematures.

The favourite smoke-composition on the Continent is a mixture of equal parts of black powder and red amorphous phosphorus in fine dust. Phosphorised antimony, a mixture of red phosphorus and sulphide of antimony, is also used. Yellow phosphorus gives good results but is less safe than red phosphorus. It is also objected to as liable to cause poisoned wounds should any of the composition remain adhering to a bullet. Napthaline has been tried and discarded; it is difficult to ignite.

HIGH-EXPLOSIVE SHELL.

These are of two kinds, namely thick-walled man-killing shell and thin-walled "mine" or "torpedo" shell.

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Page 64.—The Swedes are trying the Holmgren shrapnel with bullets set in smoke composition.

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Mine shell are now rarely used in field gun equipments, since the difference of length between a shell filled with lyddite, specific gravity 1.6, and a shrapnel of the same weight, filled with bullets, is such that the two shell cannot be made to shoot alike, and a separate range-table has to be used for each shell. Mine shell are moreover dangerous, since they contain a quantity of explosive sufficient to destroy the gun if burst in the bore. They are however used in field howitzers, which require a powerful shell for attacking field entrenchments.

Thick-walled H.E. shell are intended for the attack of materiel and of troops behind steep cover, where they cannot be reached by shrapnel. They are of hard brittle steel, and the gun-cotton burster is only large enough to break up the shell into a sufficient number of man-killing fragments. The original German Sprenggranate was of this type, and was intended principally for use with a time fuze. The idea was that when burst in air over the crest of a parapet the splinters would strike vertically downwards, killing the men behind the parapet. But after several years of experience the Germans found that with this nature of fire the expenditure of shell required to produce a number of hits sufficient to dislodge the defenders was greater than when percussion shrapnel were used to cut down the crest of the parapet. High-explosive shell are therefore now used principally with percussion fuzes.

High-explosive shell are nearly useless against infantry in the open, as the effect is very local and the men are safe at a comparatively short distance from the point of burst.

A thin-walled "mine" shell of 2.95″ calibre contains from 12 to 14 oz. of high explosive, whereas the usual charge for a thick-walled shell is 4 oz. of nitro-powder, besides the smoke-producing charge.

A thick-walled H.E. shell does not differ very much in length from a shrapnel of the same weight, and it is possible, by modifying the shape of the heads of the two projectiles, to get them to shoot practically alike.

Fig. 43 represents a Krupp design of H.E. shell which is believed to have been adopted by several foreign powers.

This is a segment shell with a burster of ordinary smokeless nitro-powder in the space surrounding the central tube. The base chamber contains a smoke-producing charge of equal parts of black powder and red phosphorus dust. On explosion the flash from the fuze passes down the central tube to the smoke-producing charge, thence through the fireholes in the diaphragm, which are plugged with gun-cotton, to the burster, which is then (at least partially) detonated.

The angle of opening is stated to be about 120°. When burst in air in front of a gun-shield the heavy segments will penetrate the shield; or if burst on impact on the gun or shield the effect will presumably be to disable the gun and detachment.

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COMPARATIVE EFFECTS OF PERCUSSION SHRAPNEL AND HIGH-EXPLOSIVE SHELL.

On the strength of experiments conducted by Messrs. Krupp and Ehrhardt it has hitherto been maintained, in Germany and elsewhere, that percussion shrapnel shell were comparatively inefficient against shielded guns. It is known that the H.E. shell bursts

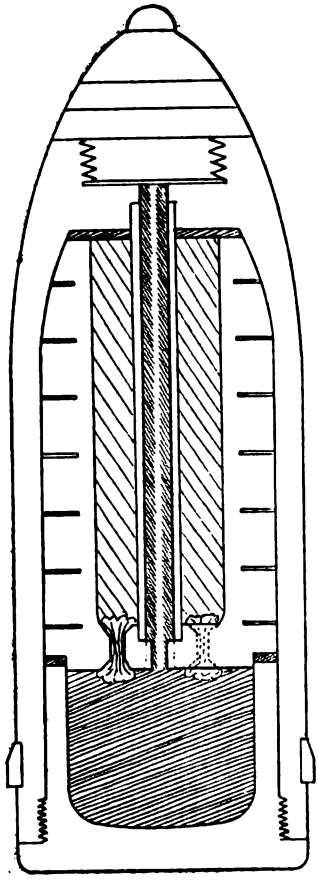

FIG. 43.

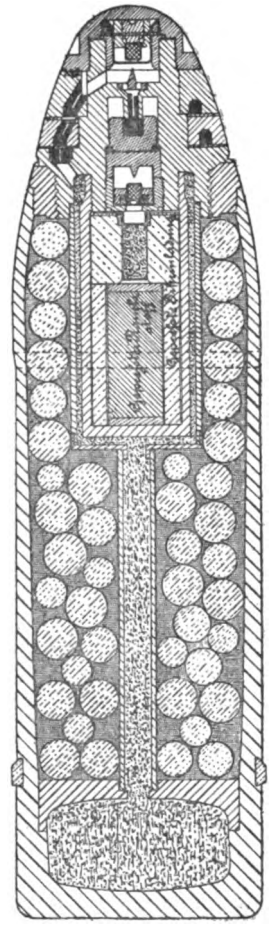

FIG. 44.

instantaneously on striking the gun-shield, making a hole about a foot in diameter, killing the detachment, and wrecking the sights and fittings of the gun. And till lately it has been supposed that a shrapnel cannot be made to burst instantaneously on impact, but that it will merely punch a round hole in the shield and burst some yards behind the gun. Recent experiments with percussion shrapnel have however given unexpectedly good results. It is found that with a well-designed fuze and shrapnel with the central tube filled with perforated powder-pellets, the shrapnel can be made to explode as it passes through the shield.

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The effect is much less than that produced by the H.E. "mine" shell, which can be relied upon to kill the gun detachment and the ammunition numbers behind the wagon alongside. But still the shrapnel does open as it passes through the shield, and kills at any rate both the numbers on that side of the gun, besides doing considerable damage to fittings. And this fact is not without importance as affecting the vexed question of the relative numbers of shrapnel and H.E. shell that should be carried.

In this connection it may be noted that recent experiments carried out by the German Government at Jüterbog have led to the conclusion that a percussion shrapnel pitching in a wagon or limber full of ammunition will blow it up as effectively as a H.E. shell would do.

Much, however, depends on the interior arrangement of the wagon fired at, and it is still an open question whether a modern "cellular" or "honeycomb" ammunition box, filled with fixed ammunition, would blow up. From past experience it would appear probable that only the shell or cartridge actually struck will explode, merely wrecking the ammunition box without injury to men standing at a short distance away.

Special Protection of Ammunition Boxes.

Much attention has been devoted to the protection of ammunition boxes in action from high-explosive shell fire. It has been found experimentally that if a shield of thin plate (or better, stout wire netting) is placed in front of the ammunition box, and 15 to 20 cm. (6 to 8 inches) clear of it, the effect is to cause a H.E. shell which strikes the netting to detonate outside the ammunition box, so that the contents of the box are not affected by the explosion. It has yet to be determined practically whether the risk of a box being struck is sufficient to warrant the addition of this encumbrance.

Incendiary Effect.

German experiments with H.E. shell have led to the conclusion that these are of little use for setting fire to buildings. But percussion shrapnel containing large driving charges of black powder are found to have considerable incendiary effect.

COMBINED SHRAPNEL AND HIGH EXPLOSIVE SHELL.

When the detonator of a H.E. shell fails to act with sufficient sharpness, the effect is that the picric acid or other H.E. charge does not detonate, but simply takes fire and burns. It has been proposed to take advantage of this fact to make a shell which shall be effective both as a shrapnel and as a H.E. shell.

Suppose a shrapnel shell with the bullets packed in, say, ammonal or gun-cotton powder. (Lyddite would not do, since in contact with lead it forms picrate of lead, a sensitive and dangerous explosive.) Suppose the T. & P. fuze such as to explode the powder charge in the ordinary way when burst in air, but to detonate the high explosive among the bullets, by means of a detonating primer, when the percussion arrangement acts on impact. Then in the first case the high explosive would merely burn and act as a smoke-producer when the shell opened; in the second case the shrapnel would become an effective high-explosive shell.

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It is understood that the French Government are carrying out experiments with projectiles of this nature, with the special object of obtaining a projectile suited to the attack of shielded guns; and that the results, up to the present, have been so far satisfactory that a shell of this nature has been introduced for the short 4.7 field gun.

The Ehrhardt High-Explosive Shrapnel is on a novel principle. As will be seen from Fig. 44, it contains a small high-explosive shell in the head. When burst as a time-shrapnel the flash passes round the H.E. shell to the base-burster; the bullets are blown out in the usual way, and the head with its high-explosive charge goes on and detonates on impact, affording a valuable means of observing and correcting the trajectory of the shell.

When burst on impact, as against a gun-shield, the high-explosive charge detonates and the bullets surrounding it are blown out laterally.

The primâ-facie objection to this form of field H.E. shrapnel is the loss of bullet capacity; but the makers claim to get 47% of bullets into them besides the high-explosive burster.

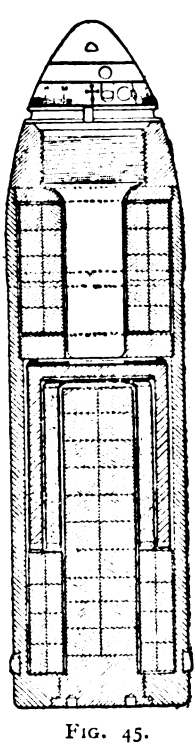

FIG. 45.

When used as a ranging projectile on graze the H.E. burster prevents the burst from being smothered in the ground, and, with the base burster, gives a conspicuous cloud of smoke. It also keeps the bullets off the ground and renders the projectile more effective when burst on graze than the ordinary shrapnel.

The Ehrhardt "Scatter Shell" is a segment shell of peculiar construction. (See Fig. 45.) The relatively small H.E. burster, of nitro-powder, is surrounded by a steel cup. The effect of this is to propel the segments in front of the cup forward with great force, so that when the shell is burst in air 100 yards short of a shielded gun the segments will pierce the gun-shield.

The angle of opening, as regards the segments in front of the cup, is 24° at medium ranges. This relatively small angle of opening is secured by enclosing the mass of segments in a leaden envelope which reduces the dispersion on the principle of the bullet-cage used in our 15-pr. B.L. shrapnel. The segments in rear of the burster fly out at an angle of about 120°.

This projectile cannot be expected to be effective against infantry targets. But it seems well adapted for the attack of shielded guns. For the probability of hitting a shield with a time-shell giving a 24-degree cone of segments is much greater than that of making a direct hit on it with a percussion H.E. shell.

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Page 68.—The Ehrhardt H.E. shrapnel, 1907 pattern, has the H.E. charge in the fuze instead of among the bullets. The useful weight is 47% as before.

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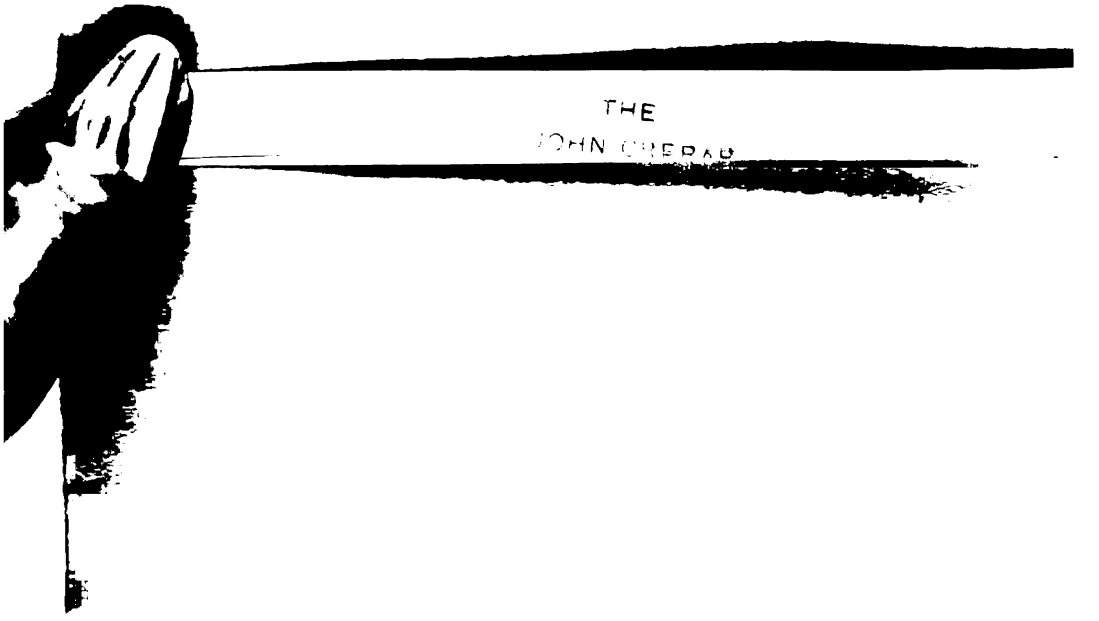

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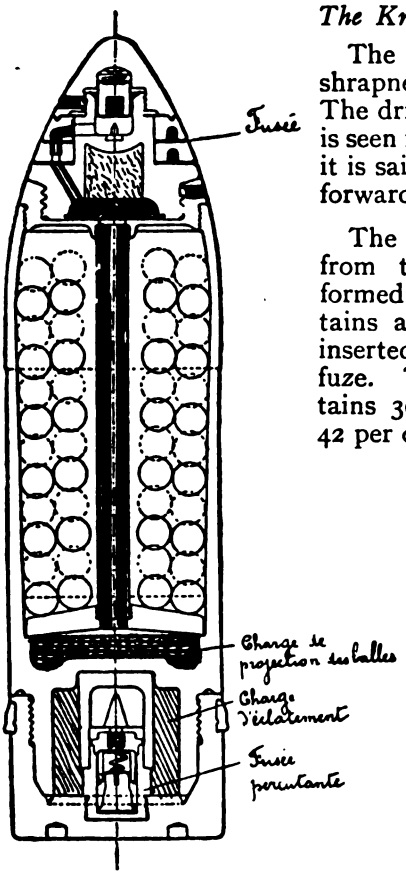
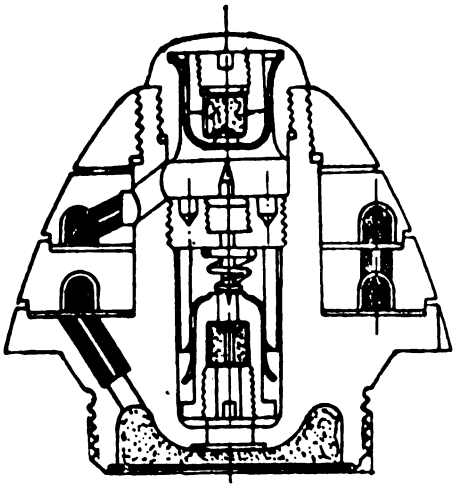


FIG. 46.

The Krupp High-Explosive Shrapnel.

The front portion of this is an ordinary shrapnel with time and percussion fuze. The driving charge of compressed powder is seen immediately behind the diaphragm; it is said to give the bullets an additional forward velocity of 200 fs.

The rear portion is completely separated from the front portion by a partition formed in the metal of the body. It contains a charge of $1\frac{3}{4}$ oz. high explosive, inserted from the base, and a percussion fuze. The shell weighs 14.3 lbs. and contains 300 bullets of 50 to the pound, or 42 per cent. of bullets.



FUZES.

The general action of percussion fuzes and time and percussion fuzes is well known. The type of fuze now adopted in all Q.F. equipments (except the French) is the double-banked fuze show in the next illustration.

The advantage of the double ring of composition is to give a great length of composition, and more accurate burning. This is explained by the diagram annexed, which represents a portion of the two composition rings.

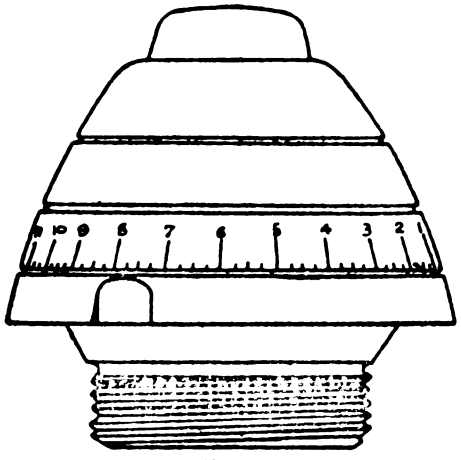


FIG. 47.

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Let A be the channel conveying the igniting flash to the upper ring, B the channel from the upper to the lower ring, and C the channel leading to the powder-chamber. Then if the lower ring be shifted from zero say one inch to the left, the fire has to burn round the upper ring from A to B, and then back again round the lower ring from B to C, a distance of two inches, or double the distance to which the lower ring was moved. Triple-banked and quadruple-banked fuzes on the same principle have been designed, but have not at present been introduced.

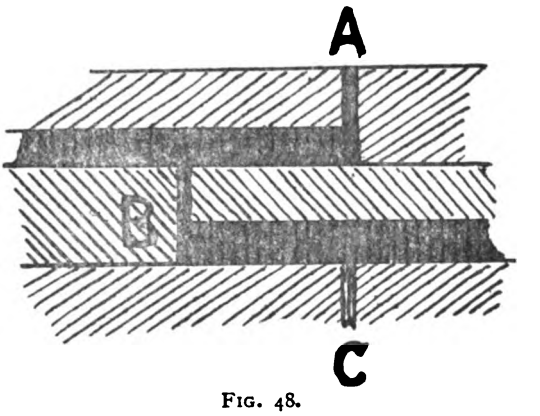

FIG. 48.

For the sake of lightness, Q.F. fuzes are made of aluminium. Since however this metal is injuriously affected by the fuze composition, the composition channels are preferably lined with brass.

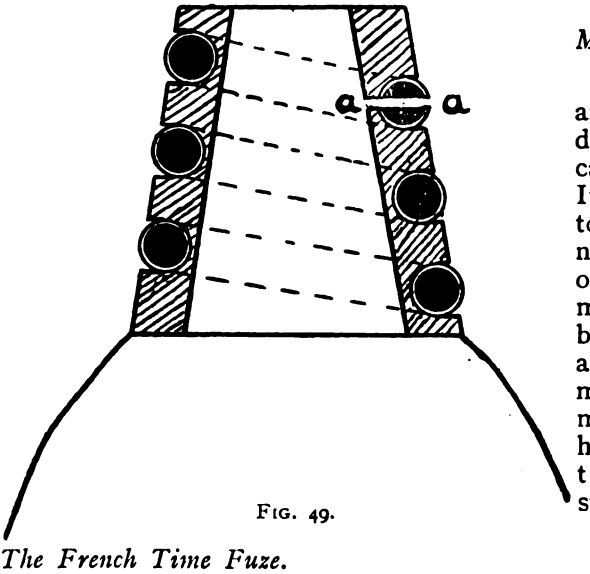

FIG. 49.

Magnalium Fuzes.

Aluminium fuzes are fragile and easily damaged if always carried in the shell. It has been proposed to make them of magnalium, a new alloy of aluminium and magnesium, said to be as strong as brass and as light as aluminium. The new metal has however hardly yet reached the commercial stage.

The French Time Fuze.

Exact details of the present pattern have not been published, but it is understood that the principle is the same as that of the old French T. and P. fuze.

The composition is contained in a sealed tube of pure tin, which is wound spirally round the head of the fuze. Inside the head is the ignition arrangement. To set the fuze it is placed in the fuze-setting machine, when by forcing down a handle a piercing point is thrust through the tube of composition into the interior space of the head, as at *aa*. On discharge, the flash from the igniter passes through the hole and ignites the composition.

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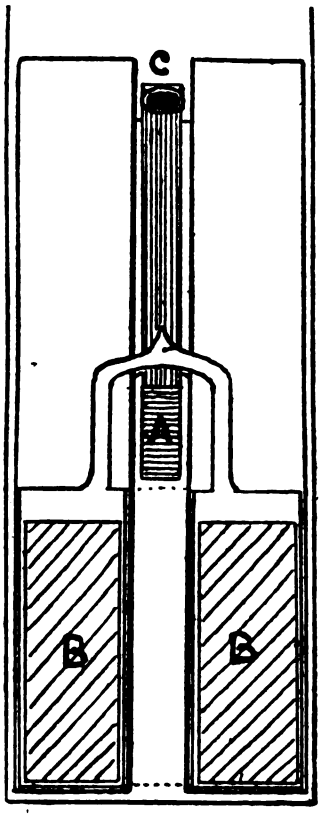

FIG. 50.

Fuzes for High Explosive Shell.

One percussion fuze which merits special description is the air-space fuze, which is intended for use with H.E. shell. The construction of this is shown diagrammatically in the annexed figure. The fuze is patented by Messrs. Ehrhardt.

Let A be the fulminate of mercury detonator, B a cylindrical primer of picric acid, protected by a stout metal diaphragm on top. Until the moment of impact B is at the bottom of the fuze, leaving an air-space round the detonator, so that if the latter goes off nothing further happens—it does not even set fire to the primer, much less detonate it. On impact the primer sets forward so as to surround the detonator, and the needle carried by the primer strikes the cap C. This fires the fulminate detonator, which detonates the primer, which in turn detonates the bursting charge of the shell.

The Bofors Fuze.

The Bofors Company, Sweden, have a base fuze on a new principle. The fuze is practically a short gun inserted in the base of the shell. On impact the fuze ignites a magazine of powder: this fires a hammer with great violence against a picric powder cap, which detonates, thus securing complete detonation of the burster. This fuze is intended to give a slight delay action and is more suitable for howitzers than for field-guns.

Mechanical Fuzes.

In this age of science, the measurement of time by burning fuze-composition would appear almost as antiquated as King Alfred's candle-clock. Many attempts have accordingly been made to arrive at a direct mechanical system of measurement of the *distance* from the gun at which the fuze is to act.

General Hiram Berdan, of the American Army, is the original patentee of the "distance fuze." A hanging weight suspended from a spindle pivoted in the axis of the shell was made to impart motion to worm gearing as the shell revolved about it, and, after a certain number of revolutions, to explode the shell. The distance at which this happened depended on the twist of the rifling and the velocity of the shell, and did not vary so long as the mechanism worked as intended. Many inventors have taken up this idea, and it still turns up from time to time at the War Office. But no one has yet succeeded in overcoming the tendency of the weight to take up the rotation of the shell instead of hanging straight down from its spindle.

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In another form of mechanical fuze the time is measured by a tuning-fork, unlocked and set in vibration by the shock of discharge.

The following are the principal types of fuze which have been tried:—

1. Fuzes in which a heavy weight is hung from pivots in the axis of the shell while the shell rotates about it.

2. Wind-vane fuzes, in which a vane pivoted on the nose of the fuze is held from turning by the air-pressure, while the shell rotates.

3. Turbine fuzes, in which a turbine wheel set in the head of the shell is rotated by the air which enters the open nose of the shell.

4. Air-pressure fuzes, in which the air slowly presses in a disc in the head of the fuze.

5. Clockwork fuzes with spring or recoil escapement.

6. Brake fuzes, in which the velocity of a clockwork train is regulated by a centrifugal brake.

7. Powder-pressure fuzes, in which a train of wheels is set in motion by the pressure of the powder-gases.

8. Centrifugal water-fuzes, in which the water is driven out from a central chamber, through a hole of given diameter, by the centrifugal force due to the rotation of the shell. The rate at which the water escapes is supposed to be uniform, and to afford a measure of the number of the rotations of the shell, that is, of the distance travelled. As the water escapes a spring plunger descends, and when the plunger gets to the bottom of the water-space a trigger is released and the shell exploded.

Personally I am of opinion that success is most likely to be achieved by substituting a gyroscope for the hanging weight. If a heavy fly-wheel be pivoted at right angles to the shell, hung in a frame pivoted in the axis of the shell, and if the wheel be revolved by a strong spring wound up before loading and released on discharge, then the wheel will actively—not passively, as in the case of a weight—resist any attempt to make the frame take up the rotation of the shell. If this be combined with a train of wheels arranged to release the striker after a certain number of revolutions of the shell, we shall have a theoretically perfect mechanical fuze. The practical difficulty is to make the pivots small enough to turn easily and yet strong enough to stand the shock of discharge.

Many mechanical fuzes have been invented, but so far no efficient substitute for the composition fuze has been discovered. Yet the composition fuze has many defects, and a serviceable mechanical fuze would double the efficiency of the gun. It is to be hoped, therefore, that there will arise in the Regiment some mechanical genius who will supply this long-felt want.

A good specimen of the mechanical fuze is the following:

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Meig's and Gathmann's Fuze.

American Patent, 772470 of 1904. Fig. 51.

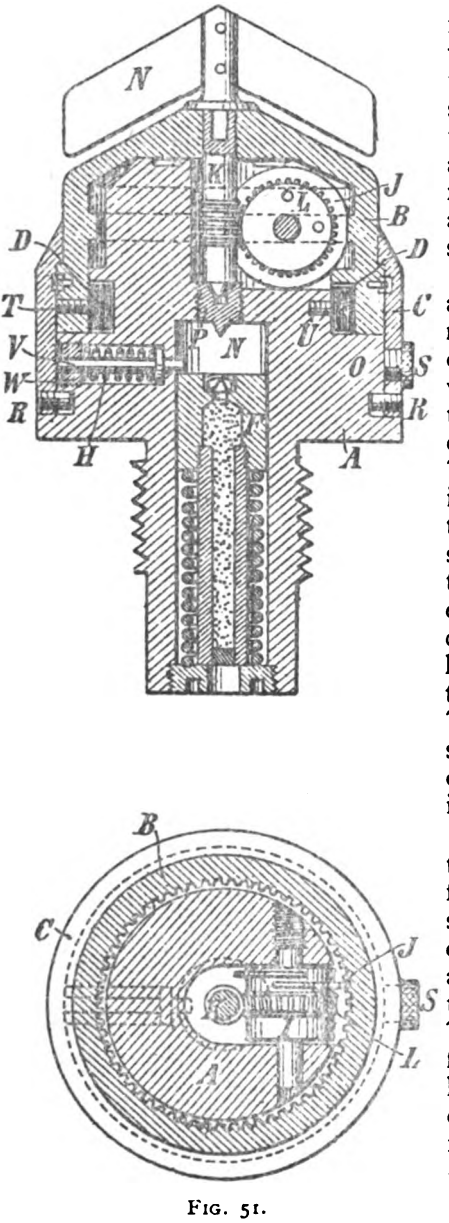

FIG. 51.

In this fuze a spindle is kept from rotating with the shell by vanes as in the Maxim fuze, and this relative motion allows a spring to unwind. This spring turns a setting plate, which after a given portion of a revolution releases a safety bolt and allows a striker actuated by a spiral spring to fire the fuze.

K is the spindle, stepped upon a plug P which carries the needle N. The endless screw on the spindle engages with the worm wheel L. The axle of this wheel carries the worm J carrying one turn of thread. The worm J engages with teeth inside the dome, which can be turned to set the fuze. A coiled spring D is fixed at one end to the fuze, at the other to the dome, and tends to revolve the dome on its seat. The dome is held down, yet so as to be free to turn, by the setting ring C. The ring has ratchet teeth inside so that it can only be turned in one direction, namely that tending to wind up the coil spring.

The striker F, which carries the cap, is in the stem of the fuze; it is actuated by the spiral spring surrounding it. It is held down by the locking-bolt V, actuated by the spring W, which tends to withdraw it outwards. The locking-bolt is prevented from moving outwards and unlocking the striker by the wall of the setting-ring, against which it abuts; when the hole O comes opposite the locking bolt the latter is free to fly out, allowing the striker to fire the fuze.

Before loading the hole O is closed by the milled-headed screw S.

The spring constantly tends to unwind and revolve the dome, but is prevented from doing so by the worm J which engages with the latter. It is only as this worm turns under the action of the vane that the dome is allowed to revolve.

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Thus in this fuze the action of the mechanism is assisted by the coiled spring.

To set the fuze the dome and setting-ring are turned in the direction allowed by the ratchet till the hole O is at a given distance (corresponding to a given number of turns of the shell in flight) from the locking bolt.

During flight the worm rotates and allows the dome to turn back again till the hole comes opposite the locking bolt and the fuze fires.

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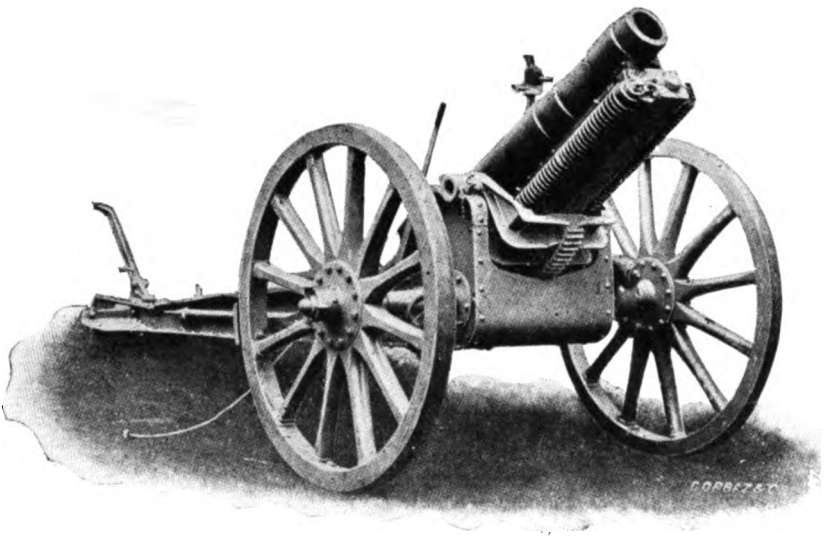

KRUPP 4.7″ Q.F. FIELD HOWITZER.

1904.

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CHAPTER X.

THE Q.F. FIELD HOWITZER.

Definition.

A field howitzer is a gun capable of throwing a heavy shell at angles of elevation up to 45%, and capable of being drawn at a trot by a six-horse team.

In practice these requirements, as worked out by the leading gun-makers, are satisfied by the following conditions:—

Weight of howitzer and limber, without gunners...	35 to 40 cwt.
Weight of shrapnel or H.E. shell	35 to 45 lbs.
Maximum muzzle velocity	1000 fs.
Calibre...	4″ to 4·7″
Rate of fire...	4 rounds per minute.
Recoil of howitzer on carriage	3 to 4 feet.
Length of howitzer, about	4 feet.

Besides the field howitzer proper, there is also in existence a type known as the heavy field howitzer, with a calibre of about 6 inches, weighing some 60 cwt. behind the team. This type (which is said to be favoured by the German Military authorities) is not a true field gun, but rather a siege gun or gun of position. A good specimen of this type is the Schneider-Canet howitzer described below.

Tactical Employment of the Field Howitzer.

The special features of the field howitzer, which differentiate it from the field gun, have been developed to suit the purpose which it is intended to fulfil.

A field howitzer serves two purposes—

1. To convey a heavy shell, charged with high explosive, to a given distant point.
2. To deliver a shower of effective shrapnel bullets, striking downwards at a steep angle of descent over an enemy's entrenchments or behind his gun-shields.

As regards the first point, the striking velocity of the H.E. shell is a matter of minor importance. The great thing is to get the shell to the desired point with as little effort as possible. And this is effected with a short gun and a small charge by using angles of elevation up to 45°.

As regards the second point, the question is more complicated. The striking energy of the bullets must not be below the 60 foot-pounds limit fixed in Chapter XVIII. Yet the muzzle velocity obtained from a short howitzer is low, and the striking velocity lower still. The difficulty is met by artificially increasing the bullet velocity by the use of a heavy driving charge in the shrapnel, and by using heavier bullets than are employed in field guns. This will be further considered under the heading of Howitzer Shrapnel Fire.

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THE HOWITZER.

Construction.

The charge of smokeless powder employed in a howitzer rarely exceeds one pound, and the pressure in the chamber does not rise above 10 tons. The strain upon the metal is therefore not very severe. Moreover, the length of recoil possible in a howitzer is limited to about 36″, as otherwise the breech would strike the ground when firing at high angles. It is therefore necessary to keep down the recoil-energy by putting as much weight as is available into the howitzer itself. (See Chapter on Recoil.) A field howitzer is therefore as a rule heavier than is necessary to stand the strain of explosion, and has a considerable surplus of strength in hand.

Calibre.

The weight of the howitzer and carriage is, broadly speaking, proportional to the muzzle energy. Now, if the muzzle energy be determined by fixing the weight and extreme range of the shell, the calibre may vary accordingly as a long slender shell or a short stumpy one is adopted. If the weight of the shell is to be 35 lbs., the calibre may be anything between 4″ and 4.7″. The 4″ shell will range further with the same muzzle energy, but, being longer, it will be more difficult to keep steady than the 4.7″ shell, and it will require a sharper twist of rifling. The best calibre for a 35 lb. shell has still to be determined. But hitherto it has been found that in most cases a short thick shell shoots better than a long thin one, and this is a consideration which has to be balanced against the longer range of the 4″ shell.

Rifling.

The accuracy of fire of a howitzer depends to a great extent upon the rifling and the driving band. Very little is definitely known as to the determination of the best possible angle and shape of groove for a given projectile, and the design of the rifling of a new howitzer is largely empirical. The difficulty lies in the fact that the shell has to change direction in flight through a large angle, since the sum of the angle of elevation and the angle of descent often exceeds a right angle. If therefore the twist of the rifling is excessive, having regard to the length of the shell, then the shell will tend, after passing the vertex of the trajectory, still to keep its original position with the nose pointing upwards, and will come down more or less sideways. If, on the other hand, the twist be insufficient, then as the velocity increases during the fall of the shell from the vertex the shell will become unsteady and wobble or even turn over.

In either case the result will be a serious loss of accuracy.

It is therefore of great importance that the twist of the rifling be such as exactly to suit the design of the shell.

Of the two evils, too much or too little twist, the consequences of the latter must at all costs be avoided. We therefore find that howitzers are usually rifled with a sharper twist in proportion to length of shell than guns.

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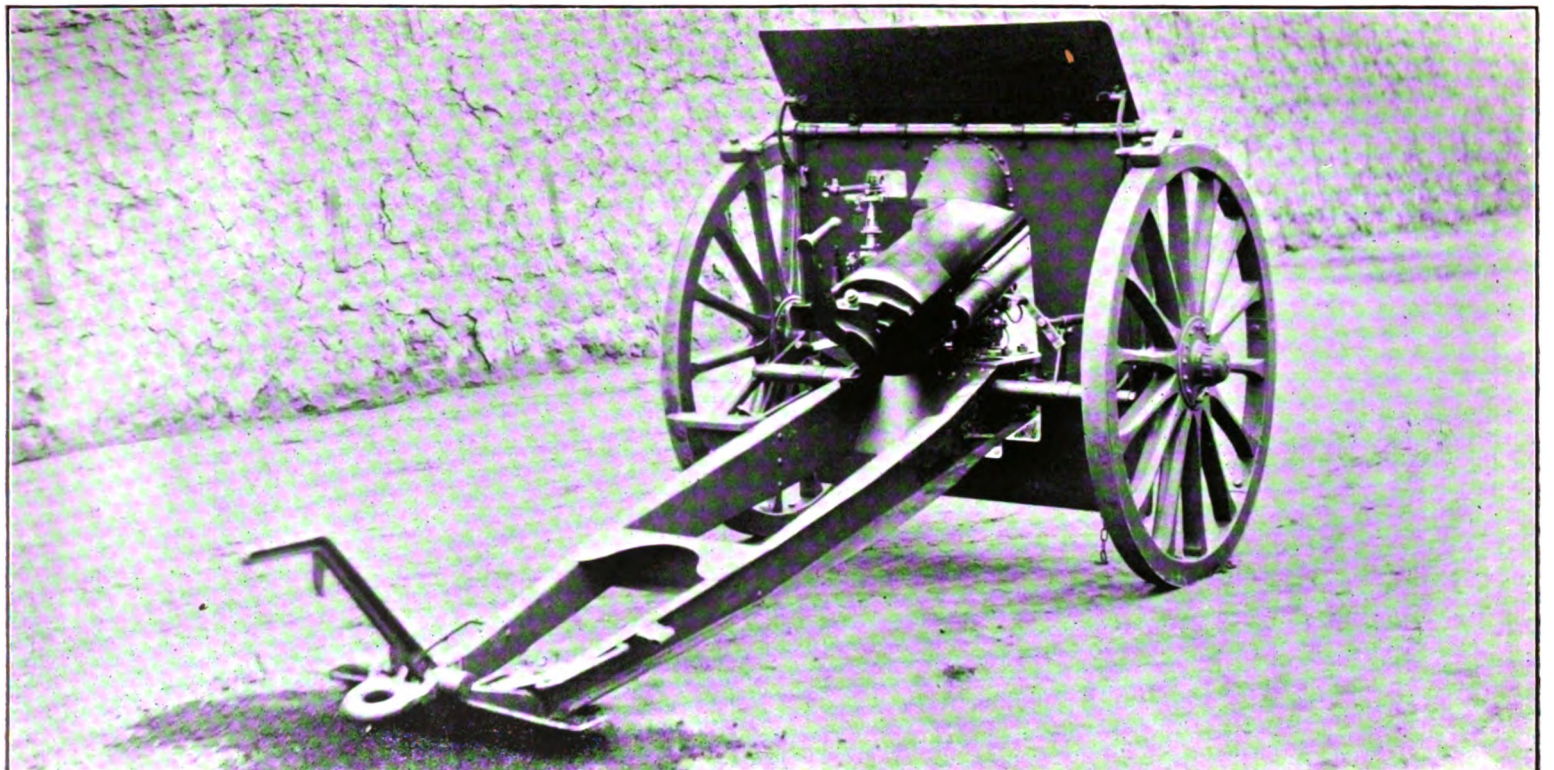

THE COCKERILL 4.7″ Q. F. HOWITZER.

1904.

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Breech Mechanism.

Extreme rapidity of action is not essential, as the heavy ammunition cannot be handled as quickly as that of a field-gun. The principal object of the designer is therefore to produce a strong and simple breech mechanism occupying little lateral space between the brackets of the carriage. The eccentric screw becomes rather cumbrous when applied to a large calibre, and the choice lies between the wedge and the swinging block, the former being usually preferred on the score of simplicity.

Sights.

The howitzer sight proper is the goniometric sight described in Chapter III., which is in effect a theodolite mounted on a pedestal attached to the cradle. This sight enables the howitzer to be layed for direction by the use of a distant aiming point, and for elevation by a clinometer which is embodied in the sight. It also automatically corrects the error due to difference of level of wheels.

In practice the sight is used as follows:—The howitzer is traversed approximately into the line of fire, the drum is set to the required horizontal angle, and the howitzer traversed till the telescope bears on the aiming-point; the base-plate is again levelled (if necessary) and the elevation finally corrected.

When once the quadrant angle and direction have been obtained, the necessary corrections at each round can be made in a few seconds.

Besides the goniometric sight, a howitzer is fitted with plain open sights, usually of the arc pattern, for direct laying on emergency. These differ from gun-sights in the extra length of the deflection bar, which has to be long enough to give deflection for drift as well as for wind.

Firing Gear.

This is of the ordinary percussion type, of simple pattern. A trip-lock is usually preferred. In this lock the main-spring is not in tension till the firing-lever is pulled; the effect of pulling the lever is first to draw back the striker against the spring and then to release it. The lock does not require to be cocked, and can be fired again after a mis-fire by a fresh pull of the lever.

THE CARRIAGE.

Owing to the great weight of the shell as compared to the howitzer, the recoil energy is greater than that of a field gun, requiring a heavy carriage to stand up to it. Thus if we suppose a howitzer firing a 40 lb. shell with a M.V. of 1000 fs., then on calculating the recoil-energy as in Chap. XVI., we find that the recoil-energy is over 10 foot-tons, or double that of a Q.F. field gun. And if the permissible recoil of the howitzer on its carriage be 3 feet, then the average pull on the piston rod of the buffer is 3.3 tons. To resist these severe strains the carriage of a howitzer requires to be considerably stronger than that of a gun.

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Overturning Strain.

Suppose the howitzer layed horizontal, height of C.G. of recoiling parts 3′6″, length of trail 8 feet. Then the pull of the piston rod, which tends to turn the carriage over backwards, is resisted by the weight of the carriage with a mechanical advantage of $\frac{8}{3.5}$; if the weight on the wheels be 22 cwt., then the resistance will amount to $\frac{8}{3.5} \times 22 = 50$ cwt., or $2\frac{1}{2}$ tons. The pull on the piston-rod being 3.3 tons, the carriage will not stand steady when the howitzer is layed and fired horizontally, but the wheels will lift about 9″ from the ground. To put the weight on equal terms with the overturning pull, the leverages at which they act must be inversely proportional—thus 3.3 tons × 2.7 = 22 cwt. × 8. To find the angle at which the howitzer will be steady, draw a side elevation and strike a circle with radius 2.7′ from the point of the trail (or, more correctly, from the centre of the spade). Then, applying the protractor, we find that the lowest angle of elevation at which the carriage will stand steady is about 10 degrees.

This may be considered a fair example of construction. To make the carriage steady for all angles of elevation we should either have to increase the weight of the carriage, or reduce the recoil-energy, or else reduce the height of the axis. The last method gives greater stability in travelling, but is open to the serious objection that there is no room for the howitzer to recoil for any distance, at a high angle of elevation, without the breech striking the ground.

The difficulty of applying the long-recoil principle to howitzers lies in the short distance between the breech and the ground.

If the howitzer is suspended in the ordinary way, with the cradle trunnions at or near the centre of gravity, then at high elevations the space under the breech available for recoil does not exceed 24 inches. This means that the force of recoil, say 10ft.-tons, has to be absorbed in a recoil of two feet, producing a pull on the carriage of five tons. At low elevations this pull is sufficient to lift the wheels off the ground.

There are several ways of getting over this difficulty. The method used by Messrs. Ehrhardt and others is known as *controlled recoil*. This has been fully discussed in Chapter VIII.

Controlled recoil secures perfect steadiness of the carriage in firing. The objection to it is the 5-ton downward strain upon the carriage at high elevations. Five tons is about the weight of a 3-horsed omnibus and passengers; so that if we imagine a crowded omnibus balanced on the howitzer, and the three horses piled on top, we shall have a fair idea of the strain to which the axletree and trail are subjected when the recoil is cut down to 24 inches.

This heavy strain has to be met by a proportionate increase of strength and weight of the carriage.

It is not possible to get increased length of recoil by setting the howitzer very high up, as this would render it unsafe to travel. But by setting the trunnions at the rear of the cradle we at any rate prevent the breech from coming nearer to the ground when the howitzer is elevated. With a 4 ft. 8-inch wheel and straight axletree the height of the axis cannot well be less than 3 ft., probably more.

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Page 79.—The later Krupp howitzers have extreme rear trunnions and a constant recoil of 48 inches. See page 271.

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This in practice allows of a recoil of 36 inches, giving a strain on the carriage of 3.3 tons only. This length of recoil is sufficient to keep the carriage steady on firing, except perhaps at angles under 10 degrees, at which a howitzer would rarely be fired.

There are several drawbacks to the rear-trunnion method. The total weight of howitzer and cradle is say 10 cwt. If this is supported on trunnions at one end and elevated at the other, then the elevating number has to lift a weight of five cwt. by turning a hand-wheel. This would require a powerful and therefore a very slow gear. To relieve the gunner of some part of this heavy labour a balance spring is fitted under the front of the cradle, or elsewhere, which takes most of the weight. But this is not a very satisfactory arrangement, since the higher the howitzer is elevated the weaker the spring becomes.

There are several other objections to the rear-trunnion method. At full elevation the weight of the howitzer is as high as the top of the wheels, and there is a risk of overturning when firing on bad ground. The rear trunnions do not give the same lateral steadiness as trunnions in the ordinary position, and errors of direction are liable to result.

Messrs. Krupp have adopted the central-trunnion system with recoil of 24 inches only, and get very fair shooting with it. Thus at 4,265 yards, with an half-charge giving an angle of descent of 45°, their 4.7″ howitzer gives a 50% rectangle 35 yards long by 12½ yards wide; with a full charge the rectangle is much smaller.

Messrs. Ehrhardt prefer the controlled recoil method, and Messrs. Cockerill use a combination of rear trunnions and controlled recoil. Trials are now proceeding in Germany and elsewhere to determine which of these three systems is the best.

Traversing Gear.

Here the difficulties to be overcome are the same as in the Q.F. field gun-carriage (see Chapter VI.) with an important additional complication. In the field gun-carriage the gun traverses above the trail; in the howitzer carriage the howitzer must traverse between the trail brackets. That is, we must find room between the brackets for the howitzer to traverse not only in the firing position but in the extreme position of recoil, some 40″ behind the firing position. The French system of traversing the whole trail and howitzer along the axletree, pivoting about the point of the trail, is objectionable on account of the weight to be moved; if we traverse the top carriage about a front pivot we require the trail brackets to be unduly wide apart: while if we mount the top carriage on a rear pivot, situated say half-way down the trail, we have still to slide the whole weight of the howitzer and top carriage backwards and forwards along the axletree when traversing. Further, since the opening in the top carriage must be long enough to allow the howitzer to recoil, we have a long and heavy top carriage. The simplest and possibly the best method is the system of mounting the cradle on a vertical pivot set either in the axletree or in a saddle between the brackets above the axletree. This, in combination with a buffer and plain or telescopic springs set under the howitzer, is perhaps the lightest form of carriage as yet devised.

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Elevating Gear.

The large angle through which the howitzer has to be elevated prevents the application of the tangent elevating screw. In the English 5″ howitzer elevation is given by a screw working on a bell-crank lever attached to a trunnion. But with a Q.F. howitzer this would only be admissible if two buffers were disposed symmetrically on either side of the howitzer so that the pull on the cradle would take place in the plane of the trunnions, thus preventing any torsional strain on the trunnion on recoil. The gear usually fitted is a toothed arc under the gun with which a worm wheel on the elevating spindle engages. All modern howitzers have a quick-motion elevating lever or gear by which the howitzer can be swung into a horizontal position for loading and then returned to its former elevation.

Buffer and Springs.

These have to be large and strong, in order to take up the high recoil-energy in the short limits of recoil which can be allowed. The springs must moreover be strong enough to lift the weight of the howitzer to the firing position at extreme angles of elevation. The hydro-pneumatic running-up gear has recently come into favour; a successful instance of its application is the Creusôt howitzer described in Chapter XXIX.

The Spade.

This must be of large area in order to hold the carriage against the severe recoil. It is made as wide and as shallow as possible. There is never any difficulty about a howitzer spade gripping, as the strong downward pressure forces it into the ground at the first round.

The Shield.

Continental gunmakers usually add a gun-shield, weighing about 1 cwt. As, however, howitzer firing will almost invariably be carried out from behind cover, it is an open question whether the weight would not be better applied in increasing the power of the howitzer.

THE LIMBER.

Supposing that the total weight behind the team without gunners is not to exceed 40 cwt., and that the weight of the howitzer in action is to be 24 cwt., this leaves only 16 cwt. for the limber and ammunition. Even supposing that 3 rounds of ammunition weighs only 1 cwt., which is a low estimate, then 15 rounds will weigh 5 cwt., which is as much as we can expect a 10 cwt. (empty) limber to carry when weighted in addition with 3 gunners, kits, and stores.

THE WAGON.

Taking the necessary supply of ammunition for one fighting day at 100 rounds for a Q.F. howitzer, then each howitzer must have 85 rounds following it in wagons. Suppose each wagon to carry half its weight of ammunition, besides gunners, and we have a total of 1½ wagons per howitzer or 9 per battery.

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And, in view of the limited supply of ammunition and small number of gunners carried by the gun-limber, six at least (if not all) of these wagons should be capable of keeping pace with the howitzer and accompanying it into action.

The external construction of a howitzer wagon is similar to that of a gun-wagon, except that the former requires no shield.

THE HIGH-ANGLE HOWITZER.

Some R.M.L. howitzers were constructed to fire at all angles of elevation up to 70 degrees.

The power of firing shrapnel at these high angles is very useful; the bullets descend vertically, and the spread due to the angle of opening even enables them to take walls and parapets in reverse. The complication entailed by varying charges can be got rid of, and fixed ammunition can be used.

There are two objections to high-angle howitzers. One is the extra weight of the carriage, which has to be strong to take up the short recoil. For the length of recoil is limited by the space between the breech and the ground when the howitzer is in the firing position.

The other objection is the extreme difficulty of getting a high-angle howitzer to shoot accurately. From what has been said about the difficulty of suiting the rifling to the shell for an ordinary howitzer, it will be understood that the difficulty in this case is much increased. For as the shell rises to the vertex of the trajectory its forward velocity falls off almost to nothing, while the spinning velocity of the shell remains undiminished. This means that the shell does not turn over at the vertex, but begins to fall base first. But for its being flat at one end and pointed at the other it might continue to fall in this fashion and come down in the same position in which it ascended. As it is, however, the shell overbalances at some moment during its descent, as the velocity increases and the air resistance becomes sufficient to overcome the gyroscopic effect of the spin. If this overbalancing always took place at the same moment, it would not effect the accuracy of the shooting. But the exact moment of overbalance is dependent on minute causes which cannot be estimated exactly, and the practical result has hitherto been that it is no more possible to predict where a high-angle shell will fall than to say in which direction a spinning top will roll when it runs down.

It is possible that the overbalancing difficulty may be got rid of by the use of special forms of shell, such as perfectly symmetrical shell, or a "tadpole" shell with heavy head and long taper base. Up to the present, however, nothing has been effected in this direction. And even if the ballistic difficulty be got over, we have still a source of error which it is impossible to contend with, namely, the wind-deflection to which a shell rising high into the air is exposed.

These considerations have led to the high angle howitzer being for the present abandoned.

The Mountain Howitzer.

Will be described under the heading of Mountain Guns.

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AMMUNITION.

Though a howitzer fires both high-explosive and shrapnel shell, it is most desirable that the shooting with the two different projectiles should be the same. Supposing the range found with H.E. shell, it would be a serious disadvantage to have to range over again on changing to shrapnel.

Now the ideal shrapnel is a case containing the maximum weight of bullets in proportion to the total weight of the shell, while the ideal H.E. shell is a thin case—a "mine" or "torpedo" shell—containing the maximum weight of high explosive. As the specific gravity of lyddite, for instance, is 1.6, while that of mixed metal is 9, it is clear that two shells of the same weight, one filled with lyddite and the other with bullets, must be of very different dimensions, and must shoot very differently.

Next comes the question whether the high explosive or the shrapnel shell is to be considered the more important nature of ammunition. For the field howitzer, preference is usually given to the shrapnel. Accordingly, the H.E. shell is made to conform as nearly as possible to the shape of the shrapnel. The thin-walled mine shell, containing perhaps 5lbs. of gun-cotton or lyddite, has to give place to a thick-walled heavily-built shell, affording space for only 1 or 2 lbs. of explosive. Even so it is hardly possible to make the H.E. shell as short as the shrapnel, and the shooting has to be adjusted by making the shells with heads of different shapes, using a longer ogive for the long shell, so as to make the two shoot as nearly as possible alike.

Howitzer Shrapnel.

A field gun shrapnel must have a small angle of opening, so as to sweep the greatest possible depth of ground. But a howitzer shrapnel comes down at a sharp angle, so that the sweeping effect hardly enters into the question. The object is rather to make bullets strike as nearly as possible vertically downwards than to cover a large area of ground. Accordingly, a howitzer shrapnel is designed to give a wide angle of opening. Suppose the angle of descent 50° and the angle of opening 24°, then the lowest bullets of the cone will strike downwards at 62°, or only 28° from the vertical. The wide angle is secured by putting a proportion of the bursting charge in the central tube, by putting a liberal allowance of coarse smoke-producing powder among the bullets, and by coning the diaphragm so as to spread the bullets outwards.

Driving Charge.

A howitzer shell, even with full charge, travels at a low velocity, and this is further reduced when the smaller charges are used. In order to make the bullets effective it is therefore necessary to increase their velocity by the use of a heavy driving charge behind them, as much as ¾lb. of powder being used.

Owing to the long time of flight, the effect of any irregularity in the burning of the fuzes is to give a greater error in the point of burst of the shell than is the case with field guns. To compensate in some measure for this, howitzer shrapnel bullets are usually made heavier than those used in field gun shrapnel.

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Weight of Howitzer Shrapnel Bullets.

The following sizes are given by General Rohne—

German Light Field Howitzer			...	48 to the pound.	
Krupp 4.1″	,,	,,	...	35 or 29	,,
Krupp 4.3″	,,	,,		... 29	,,
Krupp 4.7″	,,	,,	...	35 or 29	,,
Krupp 5.8″	,,	,,	...	35 or 29	,,
English 5″ B.L.	,,	,,	...	16 and 50	,,

The present tendency is to increase the weight of the bullets, and 16 grammes or 29 to the pound seems to be the favourite size.

Howitzer High-Explosive Shell.

As already explained, the walls of the shell have to be made very thick in order to bring up the weight without unduly lengthening the shell. It is further desirable to make the shell of hard and somewhat brittle steel, of high tensile strength. The object of this is in the first place to develop as high a pressure as possible inside the shell before it bursts (thus ensuring complete detonation of the burster) and in the second place to provide a large number of effective man-killing fragments. The harder the metal the less force is wasted in local action, that is to say in tearing the metal into small useless splinters which only fly a few yards. A shell of soft copper would, if detonated properly, be broken up into minute fragments.

Howitzer Fuzes.

The time fuze for shrapnel must be as accurate as it can be made, the object of the practice being to burst the shell above the target. This is necessitated by the wide angle of opening. The ignition arrangement further requires to be sensitive, otherwise it will not be set in action when the shell is fired with a reduced charge. Quick setting is not so essential as in a gun-fuze, and a safety pin to secure the ignition arrangement when travelling is therefore admissible.

The two types of fuze best adapted to overcome the difficulty as to sensitive ignition are the centrifugal fuze and the bolt fuze. In the latter the fuze is unlocked by a piston in the base of the shell, which is driven in by the pressure of the powder-gases. Fuzes of both these types are already in the Service, and are described in the Treatise on Ammunition.

The percussion fuze is easier to design, since with a sharp angle of descent the check of velocity on impact is sudden and violent. The difficulty is not so much in the fuze proper as in the cap or detonator which is to communicate the explosion to the lyddite. It is still doubtful whether any substance other than fulminate can be relied upon to detonate picric acid.

A fulminate fuze is dangerous both on account of its liability to explode in the limber, and of its tendency to explode prematurely with the shock of discharge. The first objection can be got over by carrying the detonator separately and only inserting it just before loading; but the second is more difficult to overcome. The most promising device is the air-space fuze, described in the chapter on Field Gun Ammunition, in which the primer is kept separate from the fulminate detonator till the instant of impact.

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In all Continental equipments this difficulty has been avoided by discarding picric acid as a burster and substituting ammonal or gun-cotton powder, which can be detonated without a fulminate primer.

The efficiency of high-explosive shell in destroying cover is much increased by the addition of a delay action to the fuze, which enables the shell to penetrate for some distance before bursting.

Howitzer Cartridges.

Case ammunition is always employed in Q.F. howitzers, not only on account of quicker loading but because it secures more regular ignition of the charge and dispenses with the complications of obturation and of firing by friction tube. It has also the merit of preventing the shell from setting back upon the powder when the howitzer is elevated. The cartridge case has a removable cover (usually of papier maché) and contains a charge of smokeless powder made up in three or more portions of different weights. By using different combinations of these three portions of the charge, a considerable variety of charges can be obtained. Provided always that the numbers of ounces in each portion are prime, that is, not multiples of each other, then the number of combinations obtainable with 3 portions is 2^n—1 or 7, with 4 portions 2^n—1 or 15, and so on.

The reason for using different charges is as follows—

Supposing that with a full charge and elevation of 45° the range is 7000 yards, then if it be required to fire at 3000 the elevation will be only some 15° and the angle of descent only 18° or so, which is insufficient for searching entrenchments. But if a $\frac{1}{3}$ charge be used the angle of elevation will be 40° and the angle of descent 45°. To get a sharp angle of descent at all ranges between 2500 and 7000 yds. it is therefore necessary to have at least 4 different charges, each giving a different muzzle velocity and requiring a separate range table of its own.

Probability of Hitting.

A howitzer range table gives the dimensions of the 50% length, breadth, and height zones in the same manner as for a gun, and the probability table is used in the same way.

Example.

How many rounds of lyddite shell from the 5 inch B.L. howitzer with full charge will be required to make one hit on a field casemate 20 yards wide and 10 yards deep at 3500 yards, presuming the range and line already found?

From the range table, the breadth of the 50% zone is 4.74 yards, depth 32.6 yards. Then the 100 per cent. zones are 4 times as large. 4 times 4.74 is 18.96; therefore all the shells will be correct for line.

As regards depth, $\frac{10}{32.6} = .3$ nearly; opposite to factor .3 in the probability table we find 16 per cent. Therefore all the shell will be correct for line, and 16 per cent. of them correct for range.

Therefore, after range and line have been correctly found to the centre of the target, we may expect to obtain 16 per cent. of hits, or 1 hit every 6 rounds.

This assumes ideal conditions for practice, and absence of wind or other disturbing factor.

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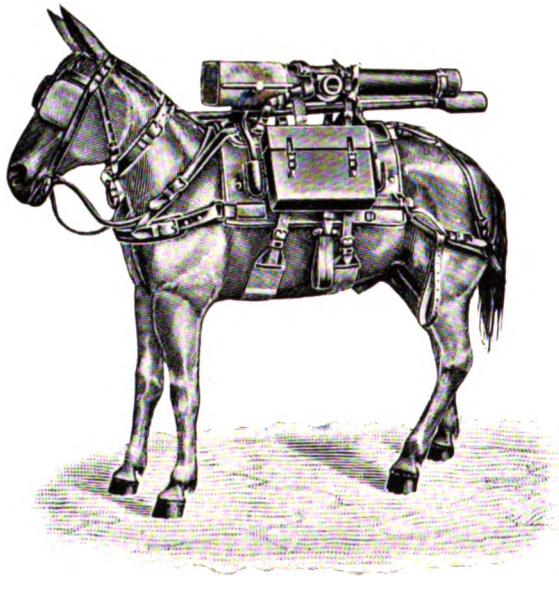

KRUPP Q. F. MOUNTAIN GUN.

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CHAPTER XI.

THE Q.F. MOUNTAIN GUN.

The duty required of a mountain gun is to support the infantry in attack or defence over ground inaccessible to field guns. It is merely a field gun sufficiently mobile for mountain transport.

Weight and Dimensions.

The weight and dimensions of the mountain gun are restricted by the following considerations:—

1. The whole equipment has to be carried on pack mules.
2. The average load which an ordinary mountain battery mule is able to carry is about 280 pounds, including 65 pounds of saddle and equipment. A few specially-selected gun mules can carry about 40 pounds more, or 320 pounds. In Spain and Italy, where exceptionally fine mules are available, some of the mountain battery loads amount to 375 pounds.
3. For work on a hillside the loads must be short, the length being limited by that of the neck of a mule. If possible no part of the equipment should be more than 4′ 6″ long.
4. The equipment must therefore be subdivided into component parts such that no part weighs more than 320 — 65 or 255 lbs., and these parts must be so designed as to be quickly assembled.
5. The number of parts into which the equipment may be subdivided is either 4 or 5. Our British mountain batteries have 5 gun and carriage mules, and yet they pride themselves on coming into action and firing the first round within one minute. Continental nations however mostly prefer to divide the equipment into 4 parts only, and they use rather heavier loads than we consider consistent with activity on the hillside.

Power of Gun.

If this were only limited by the total weight of the equipment, we should be able to obtain a gun half as powerful as a field gun. On a 5-mule basis the total weight of gun and carriage carried amounts to 10¼ cwt., or more than half the weight of a field gun. But the power obtainable is limited in practice by the weight of the gun itself. In B.L. mountain equipments the difficulty has been got over by carrying the gun in two parts which are screwed together on coming into action.

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Jointed Guns.

The 7 pr. of 400 lbs.—the original "screw-gun"—and the 10 pr. B.L. were two thoroughly serviceable equipments, and demonstrated the perfect practicability of carrying the gun in two pieces. But when it comes to making a trunnionless Q.F. gun, with guides to slide in a cradle, in two parts, the practical difficulties become formidable. It would certainly seem possible to make a jointed gun to fit into a Krupp sleigh, as afterwards described, the coupling-ring carrying one vertical lug instead of two trunnions. But so far as the writer is aware no such construction has yet been carried out, and designers of Q.F. mountain guns have been satisfied with the power that can be obtained from a gun weighing 255 lbs. Probably the maximum muzzle energy obtainable from such a gun is 120 foot-tons, which corresponds to a M.V. of 1310 fs. with a 10 lb. shell, or 1200 fs. with a 12 lb. shell.

Limitations of the Q.F. Gun.

It would therefore appear that, so far as the science of gun-making has as yet progressed, a Q.F. mountain gun must be in one piece. That is, the power of the gun must be restricted to the muzzle energy obtainable from a gun light enough for one mule to carry. Up to the present, the muzzle energy obtainable from such a gun has not exceeded 80 foot tons, and 120 foot tons may, as aforesaid, be considered a maximum. With a B.L. gun in two pieces it is easy to get 150 or even 160 tons of muzzle energy.

In other words, by adopting one of the existing Q.F. systems with a gun in one piece, we deliberately sacrifice one-fourth of the power of the gun.

We also have to use an equipment which is far more complicated and less serviceable under the rough usage which it is bound to meet with than the B.L. equipment.

On the other hand, we quadruple the rate of aimed fire; we get better shooting, and, if the shield be adopted, efficient protection for the gunners.

The increased rate of fire is of especial advantage in mountain warfare, since it enables two guns to do the work of six. On a cramped hillside it is not easy to find a position where six guns can come into action together, but it is usually possible to find room for two.

When mountain guns are used in savage warfare, they have as a rule to deal with an enemy widely dispersed and rarely concentrated to hold a position in force. It is only on exceptional occasions that the full volume of fire obtainable from the battery can be advantageously applied. It would appear, therefore, that the advantages of the Q.F. mountain gun only outweigh the disadvantages when it is to be used in war on the large scale; that is, when it is to take the place of field artillery in a pitched battle fought over ground inaccessible to wheeled carriages. Taking the case of the Indian Army, for instance, it would seem that for dealing with the frontier tribes the B.L. mountain gun is the best; but if we mean our mountain artillery

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to be capable of fighting a civilised enemy it becomes a grave question whether the B.L. screw-gun should not be replaced by a shielded Q.F. gun, and whether the Q.F. gun should not be a powerful weapon carried in two pieces.

Subdivision of Equipment.

When the gun is in one piece, the equipment naturally divides itself into four parts, namely the gun, cradle, trail, and axletree and wheels. When a very long jointed trail is used, as in the Krupp Q.F. mountain equipment, the point of the trail is carried with the wheels, which form a light load. In addition to this the folding shield, with one box (or rather two half-boxes) of ammunition forms a fifth load. The shield need not however be brought up till after the gun has opened fire.

Calibre.

To get good ballistics, the calibre of a mountain gun ought to be reduced proportionately to the reduced weight of the shell. But here the limitation of length steps in—the total length of the gun may not exceed 4 ft. 6 in., therefore the calibre must be large to give the necessary amount of pressure on the base of the shell. Hence all Q.F. mountain gun equipments are made to the 75 mm. or 2.95 in. calibre.

Construction of Gun.

The maximum weight allowable for the gun is 255 lbs. A few pounds may be gained by carrying the breech-block or wedge separately, but in view of the liability of the block to damage when out of the gun this is not usually attempted. The gun is preferably of wire construction. To keep it as short as possible it is made with an enlarged chamber to take a coned or bottle-necked cartridge, and for the same reason the conical or ogival swinging breech-block is preferred. The Nordenfeldt eccentric screw also gives a short and well-protected breech action.

Sights.

The sights must be of simple pattern, that will not be disabled when a mule rolls down the khud. Pedestal sights, rocking bars, and independent line of sight are practically out of the question. A plain bar or arc-sight is therefore preferable. At the same time, since it is the exception to find a level emplacement available, it is most desirable that the sight-socket should be capable of being cross-levelled to compensate for difference of level of wheels.

The Krupp all-round sight for mountain guns is described in Part IV.

Cranked Axletree Arms.

It is suggested that the difficulty of fitting a mountain gun with reciprocating (that is, cross-levelling) sights may be evaded by tilting the whole carriage.

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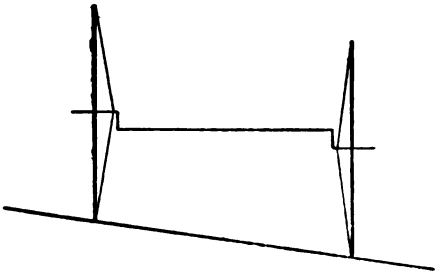

Thus in the accompanying diagram the left axletree arm is cranked up and the right arm down, so that the carriage stands level on a left-to-right slope. Now if the axletree be revolved by worm gear through 180°, the carriage will stand level on a right-to-left slope; and the carriage may be levelled, by turning the axletree, for any slope between these two extremes. On level ground the axletree will be revolved through 90° from the position shown; both wheels will then be level, but one will be some inches in advance of the other. This device has not yet been applied in practice.

Construction of Cradle.

In the Vickers-Maxim equipment the cradle surrounds the gun, which is slipped into it on coming into action. In the Krupp and Ehrhardt equipments the cradle is a closed trough or box under the gun, with vertical trunnion, containing the buffer and running-up springs, just as in the field gun equipments. There is however one difference. Instead of the gun being fitted with guide-blocks to slide on the cradle, there is a separate steel forging called a *sleigh* which slides backwards and forwards on the cradle guides. When the gun is brought into action it is merely dropped into the sleigh and secured by a keyed lug. The sleigh is never separated from the cradle, and serves to protect the guides in a contingency such as the cradle-mule falling with his load.

The Trail.

To keep a light mountain gun steady the trail must be fairly long. Three patterns are in existence. The Vickers-Maxim trail is non-folding, of moderate length, with two plain bracket sides; the Krupp trail is in two pieces, carried separately; and the Ehrhardt trail is Y shaped, the stem of the Y being hinged to fold up for transport. Both the Krupp and Ehrhardt trails are about 7 feet long, and with two big mountain gunners kneeling on the seats (which are close to the ground) give an absolutely steady carriage.

The Spade.

This is similar to that used on field guns, but proportionately small in size. It is sometimes made folding, so that it need not be used on rocky ground.

The Wheels.

These ase usually of wood, and from 2′ 8″ to 3′ 4″ in diameter.

Elevating Gear.

This is a plain screw, set near the horizontal axis so as to reduce its length as far as possible.

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Page 89.—The M.V. of the Mountain howitzer should be 900 fs., not 700 fs., and the calculation should be revised accordingly. See page 114.

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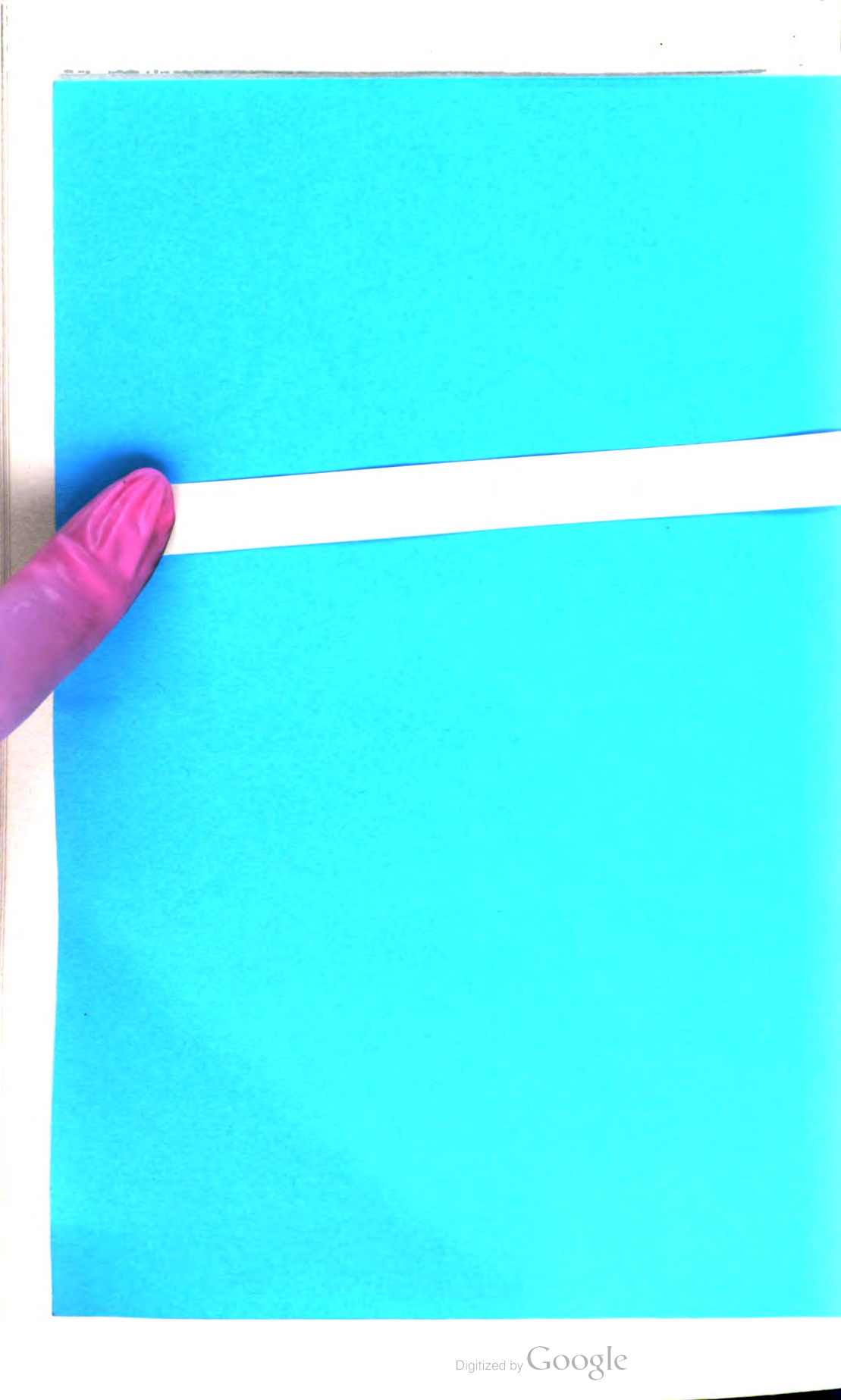

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Traversing Gear.

The cradle traverses on its vertical trunnion through about 3 degrees each way.

Shaft Draught.

On the Continent a mountain battery expects to do most of its travelling on roads. A light pair of shafts are carried which can be attached to the trail so that one mule, or two mules tandem, can pull the gun instead of carrying it.

Thus the mountain guns which General Kuroki took with him on his march from the Yalu across the mountains to Liao Yang travelled for the most part in draught. His mules and ponies were far inferior to the sturdy animals used in our service, and most of them would probably have succumbed if they had had to carry their loads all the way. As it was, they got through without much difficulty.

Shield.

A shield high enough to give cover to the detachment kneeling, and bullet-proof up to short ranges, weighs from 80 lbs. to 1 cwt. It is hinged to fold up for convenience of carrying.

Existing Q.F. Equipments.

Three principal equipments are in use, namely the Vickers-Maxim, the Krupp, and the Ehrhardt. Besides these, all the principal gun-makers have mountain equipments of their own. These are described in Part IV.

THE MOUNTAIN HOWITZER.

There has arisen of late a demand for a howitzer which shall fulfil the conditions laid down for a mountain gun, and shall be capable of throwing a shell weighing 20 to 25 lbs. with a steep angle of descent.

The construction of such a howitzer involves a new and interesting problem.

Let it be supposed that the weight of the shell has been fixed at 22.5 lbs. and the maximum range, with full charge, at 5000 yards. This will require a calibre of about 3.5 inches.

The calculation for the muzzle velocity is worked out in the examples to the next chapter. We find that a M.V. of 700 fs. will carry the shell 5000 yards with about 40° of elevation. The muzzle energy will be about 77 foot-tons.

If now we start with a howitzer in one piece weighing 210 lbs., this makes the weight of recoiling parts about 280 lbs. and the recoil energy 7 tons. Taking the weight in action at ½ ton, and the trail length such as to give a 3 to 1 mechanical advantage, then, if the howitzer is to stand steady when fired without elevation, the recoil allowed must be nearly 5 feet, which is impossible.

If we try a jointed howitzer weighing 420 lbs., then we get a recoil energy of about 3.9 foot-tons, requiring a recoil of 2.6 feet to keep it steady point blank.

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An alternative is the curved recoil gear described under Q.F. carriages. In this the downward component of the recoil energy helps to hold down the wheels when firing point blank. But even so it seems barely possible to get the required ballistics with a gun in one piece.

The next difficulty is the impossibility of finding space for long recoil under a low mountain howitzer. Even controlled recoil alone will not help us here; we must have rear trunnions and controlled recoil as well. Fortunately in the case of a mountain howitzer there is no such difficulty in applying the rear-trunnion principle as arises in the case of a field howitzer weighing 9 cwt.

No Q.F. mountain howitzer as yet exists, and the solution of the problem by the great gunmakers is awaited with much interest in Artillery circles.

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Part II.

THEORETICAL GUNNERY.

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CHAPTER XII.

THE UNIMPEDED MOTION OF A PROJECTILE.

Suppose a shell to be fired in vacuo in a horizontal direction with a velocity of 1000 feet per second. Then its path will be determined by the two forces acting on it, namely, the impetus of the shell, which tends to carry it forward in the direction in which it started; and the force of gravity, which tends to pull it down to the earth.

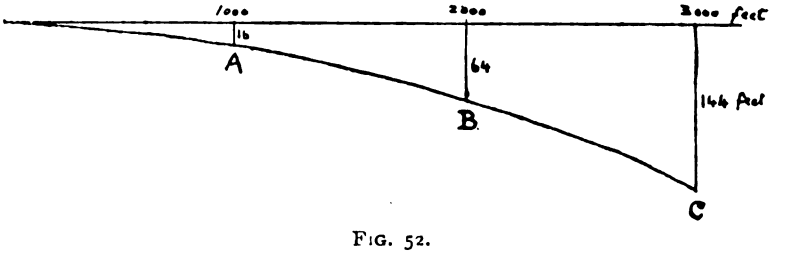

FIG. 52.

We know that a falling body drops (neglecting decimals), $\frac{1}{2}gt^2$, or—

$16 \times 1^2 = 16$ feet by the end of the first second.
$16 \times 2^2 = 64$,, ,, second ,,
$16 \times 3^2 = 144$,, ,, third ,,
$16 \times 4^2 = 256$,, ,, fourth ,,
$16 \times 5^2 = 400$,, ,, fifth ,,

and so on.

Then by the end of the first second, the shell will have travelled 1000 feet forwards and have dropped 16 feet downwards, so that its position will be at A.

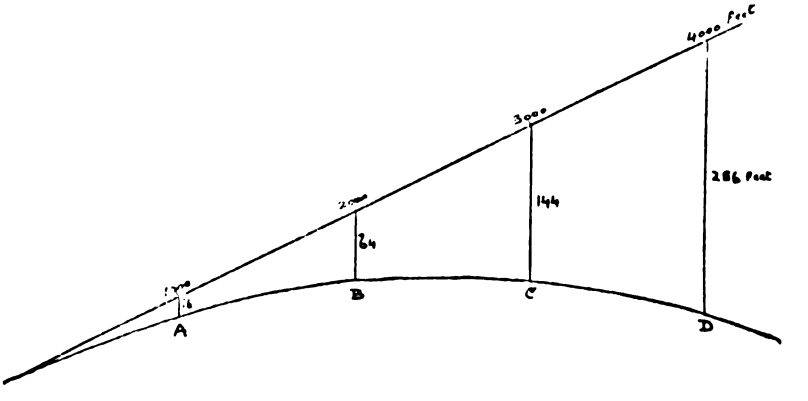

FIG. 53.

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At the end of the next second it will have travelled another 1000 feet forward, and will have dropped altogether 64 feet, and its position will be at B; and so on.

The path A, B, C of the shell is called the *trajectory*.

If the shell could be fired in a vacuum, as is imagined in the preceding paragraphs, the curve of the trajectory would be a parabola. But in practice, as will be explained hereafter, the shape of the trajectory is considerably modified by the resistance of the air.

Shell fired vertically.

If a shell be fired straight up into the air, at a velocity of 1000 feet per second, it will continue to fly upwards until the ever-increasing downward velocity due to gravity exceeds 1000 feet per second, when it will begin to fall.

To work this out practically we must use the formula.

$$V = gt.$$

Where V is the velocity, g the *acceleration* due to gravity, and t the time in seconds. Now g is always the same, since the force of gravity does not vary, and is equal to 32 feet (strictly 32.2 feet) per second.

Some confusion may arise in the learner's mind between the 32 feet of accleration due to gravity, and the 16 feet through which a body drops in the first second.

Now if a body falls from rest it falls faster and faster, until at the end of the first second it is travelling at the rate of 32 feet per second. This accleration of velocity of 0 to 32 feet per second is "g," and every unsupported body gets an extra velocity of 32 feet imparted to it by gravity every second. If the body be supported, then the effect of gravity is to cause a continuous strain on the support. (This is a point which should be impressed on every gunner supported on a four-legged horse. If the number be less than four, as is too often the case, the strain is increased in like proportion, and the importance of relieving it is still more urgent).

It will be apparent on consideration that the distance through which a body falls in the first second is not 32 feet, since the body only attains that velocity at the *end* of the second. The distance corresponds to the *mean* velocity of the body during that second, which is half-way between 0 and 32, or 16 feet.

To return to the question of the shell fired vertically upwards. As we have stated,

$$V = gt.$$

that is, for every second that the shell is in the air it acquires an increasing downward velocity of 32 feet. At the end of 10 seconds it will have acquired 320 feet per second downward velocity; but since its impetus continues to drive it upwards at 1000 feet per second, its actual remaining upward velocity will be 680 feet per second.

At the end of 30 seconds its downward velocity will be 960 feet, and at the end of 32 seconds 1024 feet; so that at some time in the 32nd second (actually at 31¼ seconds) the upward velocity will balance the downward velocity, and the shell will begin to fall again. Thenceforward the velocity will increase at 32 feet per second until the shell reaches the earth again.

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Its velocity on reaching the earth will be $31\frac{1}{4} \times 32$, or 1000 feet per second, which we see is equal to that with which it started.

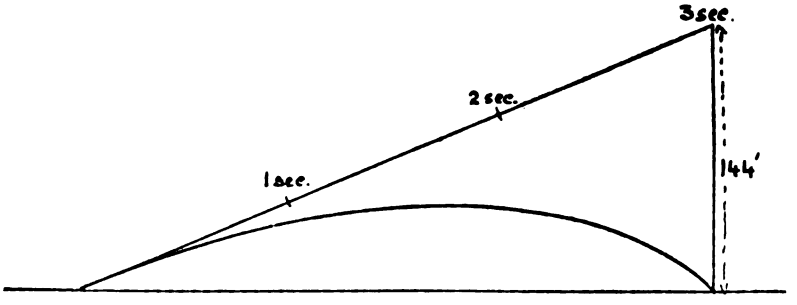

FIG. 54.

Elevation.

Since a shell is falling during the whole time of flight, then in order to reach the target it must be directed at a point above the target. The height of this point must be equal to the distance through which the shells fall during the time of flight.

Thus if the shell be fired at an object 3000 feet distant with a velocity of 1000 feet per second, it will take 3 seconds to reach the target. And since in three seconds the shell will fall $16 \times 3^2 = 144$ feet, therefore it must be directed at a point 144 feet above the target.

Since the parabola which a shell describes in vacuo is a regular curve, with its ascending and descending branches alike, the greatest height attained by the shell will be at a point half-way down the range.

For simplicity, we wlll take the case of a shell with a M.V. of 1000 feet and a time of flight of 4 seconds. Then point A at which the shell is aimed will be $16 \times 4 = 256$ feet above the target, and point C in the centre of the range will be 128 feet high. Half-way down the range the shell will have been falling two seconds, and will be 64 feet below C, or $128 - 64 = 64$ feet high. This is one-quarter of the height of A, and this proposition holds good for any shell describing a parabola.

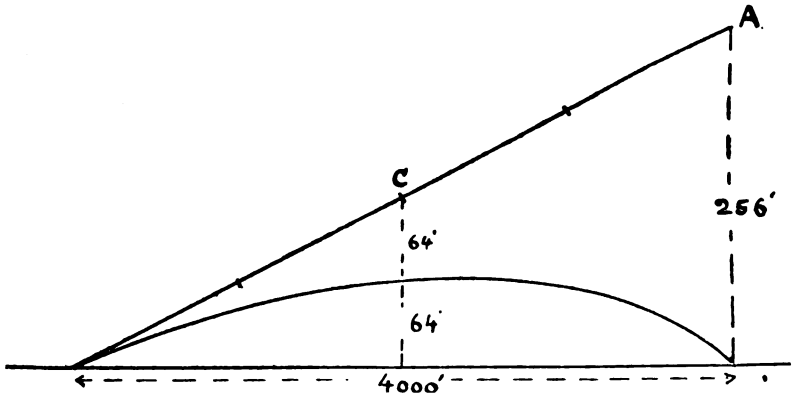

FIG. 55.

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Since the height of A in feet is sixteen times the square of the time of flight, therefore the greatest height attained by the shell is four times the square of the time of flight, or

$$H = 4T^2$$

This formula is given here because it is practically useful. At medium ranges the first half of the trajectory of a field gun fired under ordinary conditions is not very different from a parabola, and the formula is sufficiently near the truth for practical purposes. The time of flight is always known either from the range table or the fuze scale, and this gives us a ready means of determining the height of the trajectory.

Flatness of Trajectory.

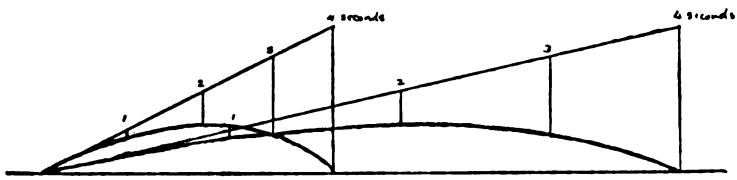

FIG. 56.

A shell which travels high above the earth to reach the target is clearly ineffective against an enemy standing anywhere except at the exact point where the shell pitches. On the other hand, a shell which flies along comparatively close to the ground will strike a six-foot man standing anywhere between the place where the shell pitches and the point where the trajectory comes within six feet of the ground. This space over which an enemy is liable to be struck by a projectile fired at a given point is called the *dangerous zone*, and it is the object of the gun-designer to make this dangerous zone as deep as possible. This is secured by *flatness of trajectory*—that is, by projecting the shell so that the height above the earth which it reaches is as small as possible.

High Velocity.

Now we have seen that it is necessary to project a shell to a certain height in order to reach a target in a given number of seconds. And no human power can alter the height through which a shell falls in a given time. All that we can do is therefore to reduce the time of flight as much as possible.

If in the foregoing example the velocity of the shell were 3000 feet instead of 1000 feet per second, it would reach the target in one second, and the greatest height, $4T^2$, would be 4 feet. If the velocity were 1500 fs. the time of flight would be 2 seconds. and the greatest height 16 feet, giving a dangerous zone of about 200 yards in front of the target.

Thus we see that to procure a flat trajectory and deep dangerous zone we must have a high velocity, enabling us to use a small angle of elevation. When we consider the motion of projectiles in air we shall find that another important consideration is a high proportion of weight of shell to cross section, which enables the shell to keep up a high velocity in spite of the resistance of the air.

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Angle of Descent.

Flatness of trajectory is estimated in practice by the smallness of the angle of descent. The field gunner's object is to burst his shrapnel so that the bullets do not pitch straight downwards into the ground, but sweep along it, so as to produce good effect in spite of inevitable errors of range. For this he requires a small angle of descent, which is only possible with a high muzzle velocity.

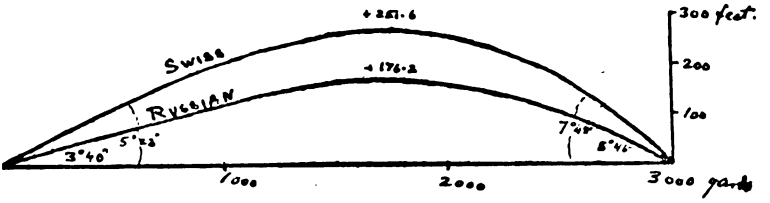

FIG. 57.

Figure 57 shews the trajectory of the Russian 1900 gun, firing a shell of 14.76 lbs. with M.V. 1930 fs., compared with that of the Swiss gun, shell 14 lbs. and M.V. 1590 fs. Figure 56 shews the effect of high and low muzzle velocity upon the trajectory for equal times of flight.

Greatest Possible Range.

The greatest possible range in vacuo is obtained when the angle of elevation is 45 degrees. When fired in air the angle giving the greatest range is not materially different, being between 40 and 43 degrees. Little is gained in range by increasing the angle of elevation beyond 35°.

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CHAPTER XIII.

THE MOTION OF A PROJECTILE IN AIR.

A projectile travelling through the air experiences a certain resistance, which shortens the distance of its flight and alters the shape of the trajectory. This resistance is greater at high than at low velocities, but the rate of increase does not follow any simple rule.

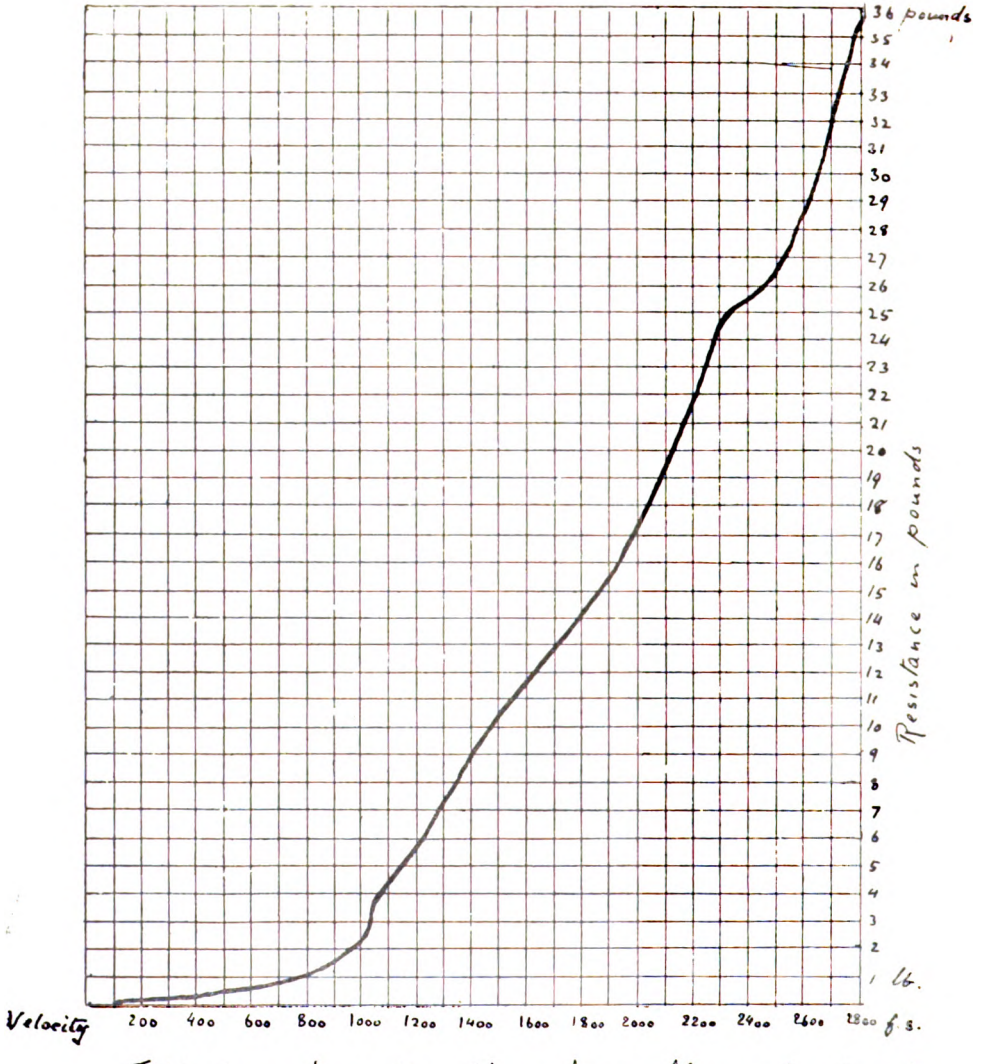

Table shewing the resistance of the air to a projectile one inch in diameter.

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Up to about 800 feet per second it increases as the square of the velocity; that is, a shell travelling at 300 feet per second experiences 9 times as much resistance as one travelling at 100 feet per second. Above 800 fs. the resistance increases in a higher ratio. For velocities between 1000 and 2500 feet per second the resistance may be said to increase roughly as the cube of the velocity.

The accompanying Table shows the resistance in pounds which the air offers to a projectile one inch in diameter, travelling at speeds from 0 to 2800 feet per second.

It will be observed that the increase of resistance is by no means regular. There is a marked kink in the curve between 1000 and 1150 fs., which latter figure happens to be the velocity of sound; and another remarkable kink about 2413 fs., the velocity at which air rushes into a vacuum. No scientific explanation of these phenomena is as yet forthcoming.

It will readily be understood that the resistance is in direct proportion to the surface offered to the air, that is to the cross section of the projectile.

Shape of Head.

The resistance is affected in a marked degree by the shape of the head of the shell. It is found that in a shell of the usual form the shape of the shoulders is more important than that of the actual point. It is suggested as an explanation of this that as the air streams outward from the point to pass over the shoulders of the shell it leaves a partial vacuum in front of the point, while the main air pressure comes near the shoulder.

The figure shows various forms of head that have been experimented with.

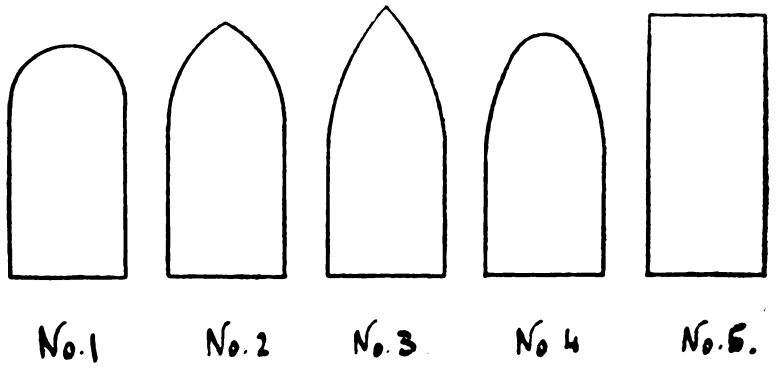

FIG. 58.

Taking the resistance offered to a shell with hemispherical head at 1 pound, it is found to be 0.83 lb. for No. 2, with a head struck with a radius of 1 diameter, 0.78 lb. for No. 3, radius 2 diameters, and the same for No. 4, which is No. 3 with the point rounded off. With No. 5, the flat-headed shell, the resistance is nearly double, or 1.53 lbs. The curve of resistance given in the table was obtained with the service shell of 30 years ago, having an ogival head struck with a radius of 1½ diameter.

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Smoothness.

It is also found that a modern smooth steel shell with driving-band meets with less resistance than the old cast-iron studded shell which were used in the 1879 equipments upon which our modern tables of resistance are founded. This requires a modification in the tabular figures for each different nature of shell.

Steadiness.

If a shell wobbles and travels shoulder first, its cross section is naturally larger, and the resistance it meets with greater, than if it travelled point first. Modern Q.F. shell are steadier in flight than B.L. and the old R.M.L., and another correction is required on this account.

Taper-base Shell.

The ideal shape of a shell intended to travel through the air with the minimum of resistance is that of a Whitehead torpedo, with a long tapering "tail." Theoretically, the shape of the base is more important than that of the head—just as, in ship designing, a fine run is found even more conducive to speed than a sharp entrance. The flat sawed-off bottom of the service shell is objectionable for several reasons. It forms a partial vacuum behind it, causing an unbalanced air-pressure on the head of the shell, and the air rushing into this vacuum forms eddies which tend to unsteady the shell. It would therefore appear desirable to introduce a more scientific form of projectile. This idea was carried out successfully in the original Whitworth solid shot, which was the first accurate artillery projectile ever invented. But modern experiments have given less favourable results. The *Z*alinski torpedo shell, fired from an air-gun, had a habit of pitching in unexpected places. And at a trial carried out in Switzerland in 1903 it was found that although the taper-base shell ranged further than the ordinary pattern, they were decidedly inaccurate in flight. It would, however, be a mistake to condemn a theoretically sound design on the strength of a single experimental series. The failure of the Swiss experiments only showed that *something* was wrong—probably the twist of the rifling was unsuited to these particular shell. It is to be hoped, therefore, that, in spite of the obvious manufacturing difficulties, modern science may evolve a better shape of projectile than that of the cylindro-ogival shell which forms our present equipment.

Density of Air.

When the barometer is high the air is compressed and is denser than when it is low; on the other hand, when the thermometer is high the air expands and is less dense than when the temperature is low. Since the resistance to a projectile is greater when the air is denser, the pressure and temperature must be taken into account in all accurate work, such as practice for range and accuracy.

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Temperature.

Besides the effect of the temperature on the density of the air, it has another and practically much more important action, namely its effect upon the powder. All modern smokeless powders are comparatively sensitive to changes in temperature, and a rise in the thermometer usually means an increase of muzzle velocity. The amount of such increase varies for each particular size and sample of powder, and cannot well be tabulated.* For this reason in practice for range and accuracy at Shoeburyness the powder charges are carefully heated or cooled to a uniform temperature of 60° Fahrenheit.

* NOTE.—For effect of temperature on cordite, size 5, as used in field guns, see chapter on Ammunition, page 60.

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CHAPTER XIV.

BALLISTIC TABLES AND THEIR USE.

In the Text Book of Gunnery will be found a set of eleven ballistic tables, by means of which any ordinary problem in gunnery may be readily solved. The use of these tables requires only the most elementary knowledge of mathematics. It is advisable however to use either the slide rule or the table of common four-figure logarithms in working out results, as otherwise the labour of multiplying and dividing will be found somewhat tedious.

All these tables except the one for spherical bullets are calculated for a projectile with an ogival head of $1\frac{1}{2}$ diameter radius. To apply them to any particular shell a coefficient C must be employed, the value of which depends upon the shape, weight and steadiness of the shell, and also (for accurate work) on the atmospheric conditions. The method of calculating C is described below.

The Ballistic Coefficient.

The first step in applying the tables to solve a question relating to any particular shell is to find the coefficient C, which expresses the comparative relation of that shell to the "unit projectile" for which the tables are drawn up.

Now we have already shown that the resistance of the air to a shell is proportional to its cross section, that is, to the square of its diameter.

And we have no difficulty in understanding that its power of overcoming resistance is proportional to its weight—*i.e.*, that a 2 lb. shell represents twice the power of a 1 lb. shell travelling at the same speed.

Therefore to obtain the ballistic coefficient—a sort of "figure of merit" of the shell—we write $\frac{w}{d^2}$, the weight divided by the cross section, and divide the result by the various modifying factors for shape of head, smoothness, steadiness, temperature, and pressure.

(NOTE.—Instead of expressing these modifying factors as fractions, and then dividing by them, it would be simpler to express them as whole numbers and multiply by them. I have however adhered to the former method, as it is the one used in the Text Book of Gunnery.)

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These modifying factors are known as:—

(i) κ (kappa), the coefficient of shape.

For shells with 2-diameter heads, with the fuze continuing the shape of the head, κ may be taken at 0.90 to 0.95.

(ii) σ (sigma), the coefficient of steadiness.

For a Q.F. field gun, this may be taken at 0.95.

(iii) τ (tau), the coefficient of tenuity.

The longer the range the greater the height to which the shell rises in the air. At a great height the density of the air is less, and the resistance to the shell is reduced.

For any given trajectory the ballistic coefficient must be corrected for tenuity, the practical rule being that the average height of the shell is two-thirds of the greatest height attained. The greatest height can always be found if the time of flight is known, being $4T^2$. The value of τ for any height will be found in Table XI.

It should be remembered that the barometer falls approximately 1″ for every 1000 feet of height.

The product of these three factors, $\kappa\sigma\tau$, constitutes the coefficient of reduction, so that we have

$$C = \frac{w}{d^2 \times \kappa\sigma\tau} = \frac{w}{d^2 \times n}$$

Of the 3 factors two are constant for any particular shell, but the third, the tenuity correction, varies with the height of the trajectory. Strictly speaking, therefore, a different value of C must be taken for each range.

Thus, to find the ballistic coefficient of the 15 pr. Q.F. gun:

$$w = 14.3 \text{ lbs.}$$
$$d = 3''$$
$$\text{Then } \frac{w}{d^2} = 1.59$$

This shell being of good modern design with a head struck with a radius of 2 diameters, we may divide by a modifying factor of 0.75:

$$\frac{1.59}{0.75} = 2.10$$

Which is sufficiently close for practical purposes.

But when a range table or any record of the actual shooting of the gun is available, it is best to calculate C by working backwards, and trying which value of C, when applied to the ballistic tables, gives results most nearly approaching those obtained in practice.

Thus, the 15 pr. Q.F. handbook gives 10°14′ as the correct elevation for 5000 yards. Taking Table X. and trying successively C = 1.8, 2.0, and 2.2, we find that C is between the two latter figures, and is about 2.052.

Similarly with the 15 pr. B.L. shell (Mk. V) we find, by comparison of the range table with Table X., that the ballistic coefficient is 1.65.

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The difference between the two 15 pr. shell is explained by the fact that the B.L. shell weighs 0.3 lb. less than the Q.F., although of the same diameter; also the shape of the B.L. head is less favourable and the shell is not so steady in flight as the Q.F.

The difference between the two guns is evident on comparing the range tables. The weight of the charge is the same, but the ballistite* used with the Q.F. gun gives 59 fs. more velocity than the cordite, in spite of the heavier shell. The Q.F. shell keeps up its velocity better; the elevation for 7000 yards is 17°26′, or 12′ less than that of the B.L. gun for 6000 yards.

As we have said, the ballistic coefficient of the 15 pr. B.L. is 1.65. Since the shell weighs 14 lbs. we have

$$\frac{14}{3^2 \times 0.95} = 1.65 \text{ nearly}$$

or a modifying factor of 0.95 as against 0.75 for the 15 pr. Q.F. shell.

Generally speaking, we may use a modifying factor of 0.9 for B.L. field shell and 0.8 for Q.F. shell for medium ranges.

The latter figure will be found to suit the Krupp field shell.

For the 18 pr. Q.F., n varies from 0.94 at 3000 yards to 1.044 at 7500 yards.

TABLES I. AND II.

These deal with the resistance of the air, and are not generally useful.

TABLE III.

This table, called the T table, is in constant requisition. It gives the number of seconds of flight during which the speed of a shell will fall from one given velocity to another given velocity.

Thus, supposing a "unit" shell fired with a M.V. of 2000 fs., how long will it take before the velocity is reduced to 1000 fs.? Answer (neglecting decimals) 233 — 229, or 4 seconds. This must be multiplied by the ballistic coefficient to give the correct answer for any particular shell.

Or conversely, if a shell is fired at 1500 fs. what will be the remaining velocity after 5 sec.? Look up 1500 fs. and we find 232 sec. opposite to it; 5 from 232 is 227; the velocity opposite 227 sec. is 870 fs.

As a matter of fact, in using this table it does *not* do to neglect the decimals. A small fraction of a second means a good many feet of flight.

TABLE IV.

Table IV. is called the distance table. It gives the space S, in feet, in which the speed of a projectile falls from one given velocity to another given velocity. It is used in the same fashion as the T table.

* NOTE.—The ballistite charge has now been replaced by an increased charge of cordite.

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Thus, if a shell be fired with a velocity of 500 metres (1640 fs.) and it be required to know at what range the velocity will fall to 400 metres (1312 fs.) we have

$$S = C\ (S_{1640} - S_{1312})$$

Suppose that C, for a Q.F. field gun, is 2,

then $s = 2\ (43779 - 42243)$ feet

$= 3072$ feet

$= 1024$ yards.

Conversely, suppose we wish to know the remaining velocity of the same shell at 2000 yards.

Then, remembering that the distance is in feet,

$6000 = 2\ (43779 - S_v)$

$3000 = 43779 - S_v$

$S_v = 43779 - 3000$

$= 40779.$

Looking up this number in the table, we find it in the 5 column opposite to velocity 108; therefore the required velocity is 1085 fs.

In both the above examples the distance "s" travelled by the shell through the air has been taken as equal to the range measured in a straight line. This is permissible for flat trajectories up to 3000 yards or so; beyond this it entails a serious degree of inaccuracy. For longer ranges a fair approximation may be made by considering the trajectory as a parabolic curve, of which the base and greatest height ($4T^2$) are known, and correcting by the formula:

$$\text{arc} = r + \frac{8h^2}{3r}$$

Where r is the range and h the height of the trajectory. Applying this, for instance, to the 15 pr. Q.F., we find that the length of the trajectory for 6000 yards range is 6126 yards.

TABLE V.

If a shell is fired at an angle of elevation of 10° and comes down at an angle of 13°, then the direction of the shell will have changed from 10° up to 13° down, or a total of 23°.

This Table gives the means of finding the total change of direction between two given velocities; thence, if the angle of elevation is known, we get the angle of descent by simple subtraction, or vice versâ. Or if both angles are known, and also the muzzle velocity, the formula enables us to find the striking velocity.

Example:—A Q.F. shell, ballistic coefficient 2, is fired at 10° elevation; the M.V. is 1640 fs., R.V. 800 fs. What is the angle of descent?

$\delta = 2\ (D_{1640} - D_{800})$

$= 2\ (84.4 - 71.7)$

$= 2 \times 12.7$

$= 25.4°$

$= 25° 24'$

Deduct the angle of elevation and we get

Angle of descent $= 15° 24'$.

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Find the R.V. of the same shell at 4000 yards. The range table gives angle of elevation 7° 12′, angle of descent 11° 28′.

$$\delta = 7° 12' + 11° 28' = 18° 40' = 18.66°$$
$$18.66 = 2 (D_{1640} - D_v)$$
$$= 2 (84.4 - D_v)$$
$$9.33 = 84.4 - D_v$$
$$D_v = 84.4 - 9.33$$
$$= 75.07.$$

Referring to table we find this opposite to v/fs. 86, column 5; therefore remaining velocity = 865 fs.

Table V. may also be used to calculate the angle of elevation or of descent where neither of these angles is known, but the time of flight has been ascertained.

Let v_o stand for the velocity at the highest portion of the trajectory, where the shell is for the moment flying horizontally. This point may be assumed with sufficient accuracy to correspond with half the time of flight.

Let α represent the angle of elevation.
β ,, ,, descent.

Then $\alpha = C (D_v - D_{vo})$
$\beta = C (D_{vo} - D_v)$.

Example.

A French field gun is fired at a target, distance unknown, and the time of flight is observed to be 12 seconds. What is the angle of elevation?

Here V = 1740 fs., C = 2.284

Use first Table III:

$$\text{Then } 6 \text{ (seconds)} = C (T_{1740} - T_{vo})$$
$$T_{vo} = T_{1740} - \tfrac{6}{C}$$
$$= 230.3271$$
$$v_o = 1073 \text{ fs.}$$

Next we take

$$\alpha = C (D_v - D_{vo})$$
$$= C (D_{1740} - D_{1073})$$
$$= C \times 3.685$$
$$= 8.408°$$
$$= 8° 24' 29''.$$

Similarly, to find the angle of descent,

$$\tfrac{1}{2}t = C (T_{vo} - T_v)$$
$$6 = C (T_{1073} - T_v)$$
$$T_v = 227.7008$$
$$v = 886 \text{ fs.}$$

$$\text{Then } \beta = C (D_{vo} - D_v)$$
$$= C (D_{1073} - D_{886})$$
$$= C \times 5.0296$$
$$= 11.49°$$
$$= 11° 29'.$$

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If it be required to find the range,

$$s = C (S_v - S_v)$$
$$= C (S_{1740} - S_{886})$$
$$= C (44198 - 38127)$$
$$= 13870 \text{ feet}$$
$$= 4623 \text{ yards.}$$

TABLE VI.

This is more useful for howitzers than for field guns. Here ϕ stands for the angle of elevation, θ for the angle of descent, while I, the inclination of the trajectory, is obtained by multiplying D in Table V. by $\frac{\pi}{180}$ or 0.01745. The table is used in the same manner as the preceding ones.

TABLE VII.

This gives the height of the trajectory at any point down the range. It is rarely applied to field guns.

To find the height of the trajectory of a field gun near the muzzle (so as to clear a covering ridge) or near the target, it is sufficient to take the portion of the trajectory as a straight line. Thus if the angle of elevation be 3° 50′, or 1 in 15 by the table at the end of this book, then the shell will clear a bank 10 feet higher than the muzzle of the gun at 150 feet, or 50 yards, down the range.

TABLE VIII is used for High-Angle fire. It gives in a handy form the constants used in calculating the pseudo-velocities in the formula given on page 18 of the 1902 Text-Book.

TABLE IX.

This table is specially useful to the Horse and Field, being the one used for calculating the velocities of shrapnel bullets. It should be used in conjunction with the table of weights, ballistic coefficients, &c., of shrapnel bullets given at the end of this book.

Suppose a shrapnel bullet, 42 to the pound, ceases to be effective when its velocity falls to 440 fs. What is the effective range from point of burst of the bullets of a 15 pr. B.L. shell burst 3000 yards from the muzzle?

For a mixed metal bullet containing 20 per cent. of antimony, 42 to the pound, the ballistic co-efficient is .088. The range table gives us a remaining velocity for 3000 yards of 830 fs. To this we may add 100 fs. for the forward impulse given to the bullets by the base burster, making 930 fs.

Then $s = C (S_{930} - S_{440})$

(Note that the columns marked ΔT, ΔS, &c., are proportional parts, inserted to save labour in calculating for velocities intermediate between the round numbers given in the table.)

$$s = .088 (11878 - 4352)$$
$$= .088 \times 7526$$
$$= 662.3 \text{ feet}$$
$$= 221 \text{ yards.}$$

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TABLE X.

This is the most useful and most reliable table in the Text Book of Gunnery. It gives the angle of elevation necessary to carry a shell with given M.V. to any range required, or, conversely, the distance to which any shell will carry with given elevation and muzzle velocity. It is used in conjunction with a table of natural sines, or with the table of logarithmic sines given on page 346 of the 1902 Text Book.

Table X. is based on the assumption that the sine of twice the angle of elevation is equal to a function "a," depending on the height of the trajectory multiplied by the ballistic coefficient.

This is written

$$\sin 2\phi = Ca$$

To use Table X., look out in the left-hand column the horizontal line of figures corresponding to the muzzle velocity. Next divide the range R by the ballistic coefficient C; look out the value of $\frac{R}{C}$ along the top of the table. Then the figure in the horizontal line of the muzzle velocity and in the vertical column under $\frac{R}{C}$ will be the number "a." Multiply this by C, and we have the sine of twice the angle of elevation.

Thus a 15 pr. B.L. shell is to be fired from the 15 pr. Q.F. gun. The muzzle velocity is 1660 fs. What elevation will be required for 5000 yards?

The ballistic coefficient of the B.L. shell is 1.65 (see page 103 above).

$$\text{Then } \frac{5000}{1.65} = 3000 \text{ yards nearly.}$$

In line 1660 and column 3000 we find "a," 2395;

$$Ca = 1.65 \times 2395 = 3951.75$$
$$\log 3952 = 3.5968.$$

Look this up in the table of logarithmic sines, neglecting the integral part. We find that .5968 corresponds either to sin 0° 14′ or to sin 23° 20′; the latter is clearly the one required;

$$\text{then } 2\phi = 23^\circ\ 16'$$
$$\phi = 11^\circ\ 38'$$

Or, instead of taking the logarithm of Ca, we may look up 3952 in the table of natural sines in the logarithm book, where we find

$$2\phi = 23^\circ\ 17'$$
$$\phi = 11^\circ\ 38'\ 30''$$

or 1° 24′ more elevation than is required with the shell properly belonging to the gun.

TABLE XI.

This gives the correction for the height of the barometer and temperature of the air which should be applied to the tables when accurate results are required. For ordinary calculation of ranges and elevation up to 3000 yards this correction may be neglected. In the chapter on Fuzes, however, it will be noted that the height of the barometer has a considerable influence on the fuze scale.

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TABLE XII. gives some particulars of rifled guns and howitzers, now rather out of date.

TABLE XIII. is a most useful table for conversion of measures.

TABLE XIV. is out of date in these smokeless powder days.

TABLE XV., four figure logarithms, is reprinted in the present book; it is much used in gunnery calculations. The present writer prefers the slide rule.

TABLE XVI., logarithmic sines, is rather troublesome to use; the table of natural sines in the log-book will be found more convenient.

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EXAMPLES OF THE USE OF THE TABLES.

Example I.

Calculate angle of elevation of the 18 pr. Q.F. gun for 3000 yards, with M.V. 1590 fs.

$$\text{Then } C = \frac{w}{92 \times n}$$

$$\text{Take } n = 0.94$$

since the head of the shell is struck with a radius of only 1.5 diameters.

$$\text{Then } C = \frac{18.5}{3.3^2 \times 0.94}$$

$$= 1.807$$

$$\frac{R}{C} = \frac{3000}{1.807} = 1660$$

From TABLE X,

$$a_{1600} = 0.9772$$
$$a_{1700} = 1.0660$$
$$.00888$$

$$\frac{60}{100} \times .00888 = 00532$$

$$a_{1660} = 1030$$
$$Ca = 1030 \times 1.807$$
$$= 1861$$
$$\text{Sin } 2\phi = 1861$$
$$2\phi = 10^\circ\ 44'$$
$$\phi = 5^\circ\ 22.$$

Calculate the angle of descent:

We must first find the remaining velocity.

From TABLE IV,

$$S = C\ (S_{1590} - S_v)$$
$$9000 = C\ (S_{1590} - S_v)$$
$$= 1.807\ (43563 - S_v)$$
$$S_v = 43563 - \frac{9000}{1.807}$$
$$= 38583$$
$$v = 913 \text{ fs.}$$

Next, from TABLE V,

$$\delta = 1.807\ (D_{1590} - D_{913})$$
$$= 1.807\ (84.2461 - 76.9739)$$
$$= 13.14^\circ$$
$$= 13^\circ\ 8'$$
$$\alpha + \beta = 13^\circ\ 8'$$
$$\alpha = 5^\circ\ 22'$$
$$\beta = 7^\circ\ 46'$$

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To find the time of flight, TABLE III,

$$t = C\,(T_{1590} - T_{918})$$
$$= 1.807\,(232.5721 - 228.1875)$$
$$= 7.9 \text{ seconds.}$$

Example II.

Find the time of flight of the 15-pr. Q.F. shrapnel at 6000 yards.

Here the trajectory is decidedly curved, and is appreciably longer than the range. We must therefore apply the correction.

$$\text{arc} = r + \frac{8h^2}{3r}$$

Where r stands for range and h for height of trajectory, both in feet.

To calculate this we must know the height of the trajectory, which is four times the square of the time of flight,—which we do not yet know.

Now, one method of working, which is *not* recommended, would be to take the length of the trajectory as equal to the range, calculate time of flight and height, apply the correction to trajectory, recalculate time of flight and height, and so on, getting each time a little nearer to the truth. We should in fact be approaching the asymptote by the way of the hyperbola.

For all practical purposes the following will suffice—

First take the trajectory as equal to the range. From the distance and velocity table we get

$$\text{Time of flight} = 18.55 \text{ sec.}$$
$$\text{Height} = 4 \times 18.55^2 = 1377 \text{ feet.}$$

Now, even for a vertical up-and-down trajectory the difference between the length of the range and the length of the trajectory is only 2h, and for an ordinary trajectory it will not much exceed $\frac{1}{4}$h, which is in this instance 344 feet. This distance represents less than half a second at 731 fs., the remaining velocity. Take *t* then at 18.55 + 0.45 or 19 sec., and then apply the correction for curvature. We shall now get the R.V. 721 fs. instead of 731, and the time of flight 18.8 sec. instead of 18.55 sec.

The difference of $\frac{1}{4}$ second obtained between the original time or flight and the corrected one gives a fair idea of the amount of inaccuracy introduced by neglecting the curvature.

NOTE.—This approximate correction is due to Professor Foord-Kelcey, of the R.M. Academy. The true formula for a parabolic trajectory is

$$\text{arc} = 2h\left(1 + \frac{r^2}{16h^2}\right)^{\frac{1}{2}} + \frac{r^2}{8h}\log\left\{\frac{4h}{r} + \left(\frac{16h^2}{r^2} + 1\right)^{\frac{1}{2}}\right\}$$

and for a trajectery considered as a circular arc

$$\text{arc} = \frac{4h^2 + r}{4h}\,\text{Sin}^{-1}\frac{4hr^2}{4h^2 + r^2}$$

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Example III.

Find the remaining velocity and angle of descent of the French field shrapnel at 3000 yards.

First find the ballistic coefficient.

The weight of the shell is 15.88 lbs., the calibre 2.95 inches; the shell is of good design, with a head probably struck with a radius of 2 calibres, and the factor of reduction may be taken at 0.8.

$$\text{Then } C = \frac{w}{nd^2}$$
$$= 2.281$$

Next find the angle of elevation.

The muzzle velocity is 1740 fs.

Then in Table X,

$$\frac{R}{C} = \frac{3000}{2.281}$$
$$= 1315$$

Look up 1740 in the left-hand column of Table X, and 1300—1400 along the top.

Then for 1740 fs. we find, under 1300, .06219, and under 1400, .06903, difference .00684.

$$\text{Then } a_{1740} = .06219 + .00103$$
$$= .06322$$
$$Ca = .06322 \times 2.281$$
$$= .1442$$
$$\text{Then } \sin 2\phi = Ca$$
$$= .1442$$

Look this up in the Table of Natural Sines in the logarithm book, or else take the log. and use the table of log. sines in the Text Book.

We find

$$2\phi = 8^\circ\ 18'$$

Then angle of elevation, ϕ, $= 4^\circ\ 9'$.

Next find remaining velocity at 3000 yards.

From Table IV.

$$s = C\,(S_v - S_v)$$
$$S_v = S_{1740} - \frac{9000}{C}$$
$$= 40253$$
$$v = 1032 \text{ fs.}$$

We can now find the angle of descent from Table V.

$$\Delta = C\,(D_{1740} - D_{1032})$$
$$= 9.970$$
$$= 9^\circ\ 58'$$

Then angle of descent

$$= \Delta - \theta$$
$$= 5^\circ\ 50'.$$

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Example IV.

Find the ballistics of the German field gun at 5000 metres

Here w = 15, d = 3.03, n (for 5000 m.) = 0.9.

The factor 0.9 is arrived at by experience with guns firing German ammunition, and includes the correction for tenuity at 5000 metres.

$v = 1525$, $t = 17$ seconds approximately.
$h = 4t^2 = 1154$ feet.
Range = 5000 metres = 16404 feet.

$$C = \frac{15}{3.03^2 \times 0.9} = 1.815$$

$$\frac{R}{C} = 9035 \text{ feet} = 3012 \text{ yards.}$$

$a_{3000} = 2676$, $a_{3100} = 2113$, difference 137.
Difference for 12 = 16
$a_{3012} = 2692$
$Ca = \sin 2\phi = 4887.5$
$2\phi = 29° 16'$ (by Table of Natural Sines)
$\phi = 14° 38'$

Next find R.V. at 5000 metres.

Here we take the distance in feet traversed by the shell, not the range.

$$S = R + \frac{8h^2}{3R} = R + 244 = 16404 + 244 = 16648 \text{ ft.}$$

$$S = C\,(S_{1525} - S_v)$$

$$S_v = S_{1525} - \frac{S}{C}$$

$= 43275 - 9175$
$= 34100$
$v = 693$ fs.

Next find the angle of descent.

$$\Delta = C\,(D_{1525} - D_{693})$$
$= 36.9$
$= 36° 54'$
$\alpha = 14° 38'$ $\quad \beta = 22° 16'$

Next find the time of flight

$$t = C\,(T_{1525} - T_{693})$$
$= 17.88.$

Example V.

A mountain howitzer of 3.5″ calibre is required to throw a shell weighing 22.5 lbs. to a distance of 5000 yards. Find the muzzle velocity.

$$\text{We have } C = \frac{22.5}{3.5^2 \times n}$$

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In order to find n we must first find τ, the correction for tenuity, since this will make a considerable difference in a howitzer trajectory at 5000 yards.

To find τ we must know the greatest height of the trajectory, and to get this we must roughly find the time of flight.

Assume that a M.V. of 700 fs. with 40 degrees of elevation will carry the shell 5000 yards, and assume n for the present at 0.8, making C = 2.3.

$$\begin{aligned} \text{Then } \alpha &= C\,(D_V - D_{v_0}) \\ 40 &= 2.3\,(D_{700} - D_{v_0}) \\ &= 2.3\,(64.37 - D_{v_0}) \\ Dv_0 &= 64.37 - 17.4 \\ &= 47^\circ \text{ approximately} \\ v_0 &= 562 \text{ fs.} \\ t &= C\,(T_{700} - T_{562}) \\ &= C\,(222.7806 - 216.9355) \\ &= 13.43 \text{ secs.} \end{aligned}$$

This is the time to the vertex; we may take the whole time of flight at 27 seconds.

We have now some idea of what the height of the trajectory will be; for 27 seconds it will be 4×27^2 or 2947 feet.

For a mountain howitzer, working at some 2000 feet above sea level, we may take the barometer at 28 degrees; then at two-thirds of the greatest height, allowing 1″ of barometer for every 1000 feet, we have a barometric pressure of approximately 26 inches.

Taking the thermometer at 60 degrees, then by Table XI, $\tau = .866$.

Take κ the correction for the shape of head, at 0.95, and σ, the correction for steadiness, also at 0.95; then we get n, the coefficient of reduction:

$$\begin{aligned} n &= .866 \times .95 \times .95 \\ &= .7816 \\ \text{Then } C &= \frac{22.5}{3.5^2 \times .7816} \\ &= 2.344. \end{aligned}$$

Next we use Table X, which gives us the angle of elevation at which a shell with a ballistic coefficient of 2.344, fired with a M.V. of 700 fs., will range 5000 yards.

We have assumed the angle of elevation to be 40 degrees; then the angle of descent will be say 50 degrees. Now for high angle fire we use the formula on page 18, Text Book of Gunnery, 1902. Instead of writing V = 700 fs. we write

$$U = 700 \times \text{Cos } 40^\circ \times \text{Sec } \eta$$

Here $\theta = -\beta$, since the inclination of the trajectory has changed from an upward or plus angle to a downward or minus angle, and the formula for sec η becomes:

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$$\text{Sec } \eta = \frac{\text{i } 40^\circ + \text{i } 50^\circ}{\tan 40^\circ + \tan 50^\circ} = 1.63$$

From Table VIII.

$$\text{Sec } \eta = \frac{.92914 + 1.43236}{.83910 + 1.19175}$$

$$U = 623.7 \text{ fs.}$$

Then from Table X.:

$$\frac{R}{C} = \frac{5000}{2.344} = 2133$$

But the figures in the Table for 620 fs. only go up to R/C 1100. The Table goes nearly up to the limit of effective range, so we must conclude that a M.V. of 700 fs. is much too low.

Try 900 fs. Then, by a similar calculation, t = 33 sec., h = 4350, τ = .853, n = 7515, C = 2.442, U = 800 fs. nearly, R/C = 2050.

Then from Table X.:

$$a = .4021$$
$$Ca = \sin 2\phi = .983$$
$$2\phi = 79^\circ\ 26'$$
$$\phi = 39^\circ\ 43'.$$

Therefore 900 fs. will carry the shell to the required distance at slightly less than the prescribed limit of elevation.

This result may be accepted as a rough approximation. But Table X. was not constructed for the calculation of high-angle trajectories, and cannot be expected to give exact results at 40° elevation.

In this instance we have been fortunate in nearly hitting off the required elevation at the second attempt. But in tentative calculations of this kind it is best to make a bold bracket and to subdivide it as in ranging. Calculations should be made in round numbers, and intermediate figures arrived at by plotting them as described in the chapter on the Plotting Chart.

APPLICATION OF BALLISTIC TABLES TO HOWITZER FIRE.

Where strict accuracy is not required, ordinary problems in Field Howitzer Fire may be solved by the Ballistic Tables, using the formulæ for pseudo-velocities on page 18 of the 1902 Text Book. But the accurate calculation of high-angle trajectories is not a matter of simple arithmetical computation, but requires a knowledge of elementary mathematics including the integral calculus. This subject is treated fully and clearly in Part II. of the Text Book of Gunnery, 1902, and the present writer is not competent to add anything to the demonstrations there given. The student is also referred to Col. Hickman's pamphlet on the Compilation of Range Tables, which appeared in Vol. XXVIII. of the R.A. Journal. In using Col. Hickman's values of constants it must be remembered that these refer to Ingall's Ballistic Tables, and are not applicable to the Tables in the Text Book of Gunnery.

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CHAPTER XV.

ACCURACY OF FIRE.

However perfectly a gun may be layed, we never get two successive rounds to fall in the same place. This is due to variations in the strength of the powder, in the resistance offered by the driving band, in the weight of the shell, and especially in the steadiness of the shell in flight. A shell fired from a rifled gun does not travel in a plane curve, but in a spiral round and round the mean trajectory. The amplitude of the spiral tends to decrease under the influence of the resistance of the air, till at about 1000 yards the shell begins to settle down to a regular curve. In the same way a spinning top, after a first period of wobbling, "goes to sleep," and remains steady till its spin is insufficient to overcome the overturning moment due to the irregular frictional resistance of its point.

The exact location of the trajectory in the air is dependent on the shape of the preliminary spiral, and this is dependent on a number of variables, such as the exact angle which the shell makes with the gun on leaving the muzzle, the smoothness of the head of each particular shell, and the wind resistance which it happens to encounter.

The practical result is that the trajectories of a number of shell fired from the same gun at the same elevation form a bent cone, which is called the SHEAF OF FIRE.

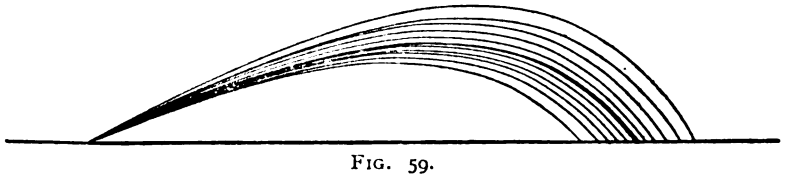

FIG. 59.

The intersection of the surface of the ground with the sheaf of fire forms an ellipse, of which the breadth is equal to the diameter of the cone, while the length increases with the smallness of the angle of descent. If the cone were circular in section, then at an angle of descent of 30 degrees the length of the ellipse would be twice the breadth, while at 5° 45′ it would be just ten times the breadth. Since however the disturbing influences which affect the range (such as the variable jump of the carriage) are greater than those affecting the direction, the ellipse is always found to be longer in proportion to its breadth than it would be if the vertical and horizontal errors were equal. The actual dimensions of this ellipse for each gun and for each range are determined by "practice for range and accuracy" at Shoeburyness. This practice is conducted with the utmost care, and all disturbing elements are as far as possible eliminated or corrected.

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Each shell and cartridge are weighed, the powder is kept at a uniform temperature, and the force and direction of wind noted for each round. The result is to give the dimensions of the area of ground upon which all shell fired at a given elevation and direction should fall.

Total Rectangle. For convenience it is usual to express this area in terms of the circumscribed rectangle. Thus instead of saying that all rounds fired from the 18 pr. Q.F. at 3000 yards are contained in an ellipse 80 yards long by $5\frac{3}{4}$ yards wide, we say that the *total rectangle* is 80 yards long and $5\frac{3}{4}$ yards broad.

Vertical Rectangle. Knowing the horizontal rectangle, it is easy to determine the dimensions of the vertical rectangle which all shots should strike. The height of this is approximately equal to the length of the total horizontal rectangle multiplied by the tangent of the mean angle of descent.

Battery Rectangle. When six guns are firing at the same target, they always make a bigger rectangle than one gun. For we have now to contend with additional sources of error, the principal being the different sighting of the six guns and the different personal error of the six layers. In practice, when the target is clearly defined, the total error should not be more than 25% greater than that obtained at Shoeburyness. If the rectangle be twice as long, it shows bad laying or neglected equipment.

The Fifty Per Cent. Zone.

If we direct a shower of shells from a gun, or a shower of pebbles from the hand, at a given mark, it will be found that these are not uniformly distributed over a space of ground, but lie more thickly towards the centre of the space. It can be demonstrated by the Theory of Probability that if the whole of the shell fall in a space 100 yards long, half of them will (on the average) be found within one quarter of that length, or 25 yards. Exactly the same result will be obtained if we measure the distance of each shell from the central one of the group, and multiply the *average* distance by the factor 1.69, which depends on the Theory of Probabilities.

Similarly, the width of the rectangle containing half the shell is one quarter of the width of the total rectangle, and the height of the rectangle containing half the shell is one quarter of the height of the total rectangle.

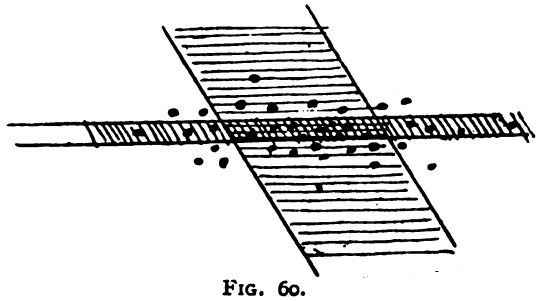

FIG. 60.

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The Twenty-Five Per Cent. Zone.

Suppose all the shell to fall within a space 100 yards long by 4 wide. Then a transverse zone or belt 25 yards in depth will include 50% of the shell. Similarly a longitudinal zone 1 yard wide will include 50% of the shell.

The central rectangle where the two zones are superposed will then contain 50% of 50% or 25% of the shell. If in the same instance all the shell fall within a vertical height of 12 yards, 50% will be in a vertical zone 3 yards high, and 25% in a vertical rectangle 3 yards high and 1 yard broad.

Probability of Hitting.

Knowing from the range table the depth, width, and height of the 50% zone for any range, the table of Probability Factors enables us to determine the chance of hitting an object of a given size.

TABLE OF PROBABILITY FACTORS.

(From Mackinlay's Text Book of Gunnery.)

The following gives the proportional width of other zones (containing a different percentage of hits) to one of 50 per cent. as unity.

Per cent.	Factor.	Per cent.	Factor.	Per cent.	Factor.	Per cent.	Factor.	Per cent.	Factor.
1	0.02	**21**	0.40	**41**	0.80	**61**	1.27	**81**	1.94
2	0.04	**22**	0.41	**42**	0.82	**62**	1.30	**82**	1.98
3	0.06	**23**	0.43	**43**	0.84	**63**	1.33	**83**	2.03
4	0.07	**24**	0.45	**44**	0.86	**64**	1.36	**84**	2.08
5	0.09	**25**	0.47	**45**	0.89	**65**	1.39	**85**	2.13
6	0.11	**26**	0.49	**46**	0.91	**66**	1.42	**86**	2.18
7	0.13	**27**	0.51	**47**	0.93	**67**	1.45	**87**	2.24
8	0.15	**28**	0.53	**48**	0.95	**68**	1.48	**88**	2.30
9	0.17	**29**	0.55	**49**	0.98	**69**	1.51	**89**	2.37
10	0.18	**30**	0.57	**50**	1.00	**70**	1.54	**90**	2.44
11	0.20	**31**	0.59	**51**	1.02	**71**	1.57	**91**	2.52
12	0.22	**32**	0.61	**52**	1.04	**72**	1.60	**92**	2.60
13	0.24	**33**	0.63	**53**	1.07	**73**	1.64	**93**	2.69
14	0.26	**34**	0.65	**54**	1.09	**74**	1.67	**94**	2.78
15	0.28	**35**	0.67	**55**	1.12	**75**	1.71	**95**	2.91
16	0.30	**36**	0.70	**56**	1.14	**76**	1.74	**96**	3.04
17	0.32	**37**	3.72	**57**	1.17	**77**	1.78	**97**	3.22
18	0.34	**38**	0.74	**58**	1.19	**78**	1.82	**98**	3.45
19	0.36	**39**	0.76	**59**	1.22	**79**	1.86	**99**	3.82
20	0.38	**40**	0.78	**60**	1.25	**80**	1.90	**100**	

Example 1.

Suppose we are firing with the 18 pr. Q.F. at 3000 yards; what is the chance of hitting a shielded gun 5′ high and 6′ wide?

From the Range Table,

50% of rounds should fall in 1.44 yards breadth, and 20 yards length. At an angle of descent of 7° 36′, or 1 in $7\frac{3}{4}$, $7\frac{3}{4}$ yards horizontal corresponds to 1 yard vertical, or 20 yards of length to $\frac{20}{7.75}$ or 2.667 yards of height.

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Here the width of the target is two yards, or 1.4 times 1.44 yards. In the table we find factor 1.39 opposite 65 per cent., that is, 65 per cent. of the shots will be correct for line.

The height of the target is 5 feet, or 0.625 times 4.7 yards. Factor 0.63 is opposite 33 per cent: therefore 33 per cent. of the shots will be correct for elevation.

33 per cent. of 65 per cent. is 21.66 per cent., that is, it will take 100 rounds to make 21.66 hits on the target, or an average of 4.7 rounds to make one hit.

This is assuming that the range is found to a yard, the laying perfect, and no wind, refraction, or other disturbing cause.

Example 2.

What is the chance of dropping a shell into a rectangular gun emplacement 3 yards wide and 5 yards from front to rear, with the 18-pr. Q.F. at 3500 yards?

Assume the parapet revetted vertical, and 3′ high. Then since angle of descent (from range table) is about 1 in 6, a parapet 1 yard high will cover 6 yards to the rear, and it will be impossible to get a shell into the emplacement without going through the parapet. Suppose that a shell striking the superior slope within one yard of the crest will penetrate the parapet, then our target is reduced to a surface 3 yards wide by one yard from front to rear.

Now the 50% rectangle of the 18 pr. Q.F. at 3500 yards is 1.75 yards wide; 3 yards over 1.75 yards is 1.7, which number we find opposite 75% in the Table, so that 75% of the shots will be correct for line.

Again, the 50% rectangle of the 18 pr. Q.F. at 3500 yards is 26 yards long; 1 over 26 is .038, which number comes just short of 2 in the table, so that 2% of the shots will be correct for elevation;

2% of 75% is 1.5% nearly.

So that in 100 shots, under ideal conditions, we may expect to put 1.5 effective shell into the emplacement.

Example 3.

The battery is being fired at by the 75 mm. French gun at 4200 yards. Is the wagon less likely to be struck if placed alongside the gun or if placed behind it?

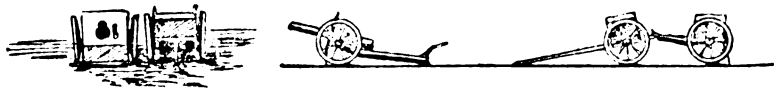

FIG. 61.

For the French gun, at this range, the breadth of the 50% zone may be taken as under—

Longitudinal	...	32 yards
Lateral	...	1.5 „
Vertical	...	5.3 „

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Consider first the chance of hitting the wagon alongside the gun. Suppose the enemy's fire directed at the gun. Then the wagon extends to a distance of about 9 feet from the centre line of the gun; if there were a wagon on each side the total width of the target would be 18 feet or 6 yards. This is just four times the 50% lateral zone, so that all the shell would be correct for line. The proportion which would hit one wagon alongside the gun is half the total less half the number which would hit the gun. The latter number corresponds to the probability factor $\frac{2}{1.5}$ or 1.33, and is found by the table to be 63%. Therefore the percentage which would hit the wagon, as far as line goes, is $\frac{100-63}{2}$ or 18½%. Next for the elevation. The angle of descent being 1 in 6, we find by graphical construction that the effective height of a wagon limbered up is about 6 feet. That is, if a screen 6′ high were placed in front of the wagon limber, any shell passing through the screen would either hit the wagon limber or the wagon body or the ground underneath. Now suppose the range accurately found, so that the mean point of impact corresponds with the point of aim, that is the ground line of the target. Then the 50% zone being 5.3 yards high, or 2.65 yards above and below the mean point of impact, the probability factor is $\frac{2}{2.65}$ or .755 and the percentage opposite to it is 39, so that 39% of the shots above the ground line, or 19½% of the whole, would be correct for elevation as regards the wagon. 19½% of 18½% is 3.61% which is the, percentage of shots which would hit the wagon.

The above calculation is useful as a theoretical example, but is not practical. On service the gun-layer would naturally aim not at the gun but at the centre of the ground line of the group formed by gun and wagon. Taking the total width at 12 feet, it follows by a similar calculation that $\frac{9.3}{2}$ = 46½% of the shots would be correct for line as regards the wagon; multiplying this by 19½% as before we get 9.1% as the percentage of shots which would strike the wagon. But in this case the percentage which would strike the gun, which is only 5′ high measured at right angles to the trajectory, is less than half of the total hits, roughly in the proportion of 5 to 6, giving 7.6% only.

Next we take the case of the wagon placed behind the gun. In

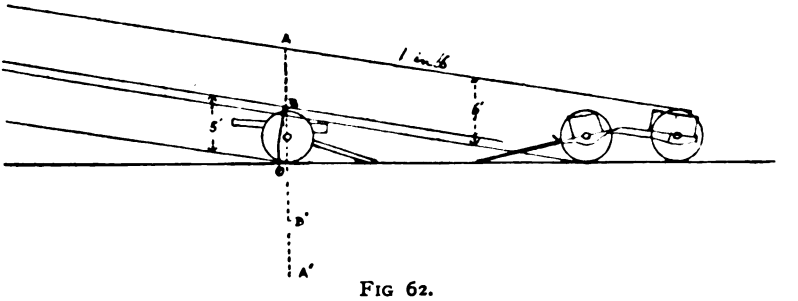

FIG 62.

Fig. 62, which is drawn to scale, the wagon is shewn in the old regulation position with the point of the pole 3 yards from the trail eye. Take the mean point of impact at O; then by measurement OA = 10.25 feet, and AA′ = 21.5 feet. The 50% zone being 5.3 yards high,

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the probability factor is $\frac{21.5}{5.3 \times 3}$ or 1.35, which, by the table, corresponds to 64%. Of these 64% half will be grazes short and the other half, 32%, will (if the line be correct) be hits upon the gun or wagon.

To find the percentage of hits upon the wagon alone, we must deduct the hits on the gun. BB′ being 10 feet, the factor is $\frac{10}{5.3 \times 3}$ or .63, and the probable percentage 33%, of which 16½% will be grazes short and 16½% hits on the gun. Therefore the hits on the wagon (subject to correction for line) will be 32% — 16½% or 15½%.

But since a proportion of these shots, though correct for elevation, will be wide, we must multiply by the probable percentage of shots correct for line. The gun and wagon are each two yards wide and the lateral 50% zone 1.5 yards; the factor is $\frac{2}{1.5}$ or 1.33, and the probable percentage 63%. Multiply by this and we have 10.4% for the gun and 9.8% for the wagon.

That is to say, that if 100 shots be fired at a gun and wagon, then, if the wagon be alongside the gun, the gun will receive 7.6 direct hits and the wagon 9.1 hits. But if the wagon be in the old regulation position behind the gun, then the gun will receive 10.4 hits and the wagon 9.8 hits.

The reason why the wagon receives fewer hits than the gun in the second case, although it offers a larger target, will be evident from the figure, which shows that with an angle of descent of 1 in 6 the gun masks a portion of the wagon. But it should be remembered that some of the hits on the gun will probably be effective on the wagon behind it.

Besides the reduced probability of being hit, the position of the wagon alongside the gun has other advantages, which will be discussed in Part III.

NOTE.—In the first edition of this book the slope of descent of the French shell was taken at 1 in 6 for 3000 yards. According to later information this is incorrect, and it is only at 4200 yards that the slope of descent increases to 1 in 6. The problem has been revised accordingly.

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CHAPTER XVI.

DEFLECTION OF PROJECTILES BY WIND.

This seems at first sight a simple matter to calculate. It would seem that we have only to calculate the lateral pressure of the wind on the shell, and thence the lateral velocity imparted to it. Unfortunately the results obtained by this method are very far from corresponding with those actually observed, the actual deflection being two or three times as great as the calculated deflections.

Younghusband's Method.

A more scientific method is given in the Text Book of Gunnery, but this method is not suitable for ordinary practical use, as the time of flight has first to be calculated to two places of decimals, a degree of accuracy to which our range tables do not pretend.

Captain Hardcastle's wind chart (which is here reprinted by permission) gives a good working approximation to the deflection required for a given force and direction of wind. It differs from other charts previously published in that it takes into account the fact that at the highest point of its trajectory the shell is exposed to a wind much stronger than that blowing on the ground level. Accordingly the scale of allowances is graduated for the known rate of increase of wind with altitude, as determined by meteorological experiments.

To use this chart, follow the circle marked with the speed of the wind till it cuts the "o'clock" of the wind. Read off vertically under the point so found the wind deflection in minutes on the scale marked with the range.

The words used to describe the strength of the wind are those used in the daily weather forecasts.

Examples of Use of Chart.

Range 3000, wind II o'clock, fresh.
Deflection 18 minutes right.

Range 4200, wind V o'clock, strong.
Deflection 22 minutes right.

Range 4500, wind VIII o'clock, moderate.
Deflection 24 minutes left.

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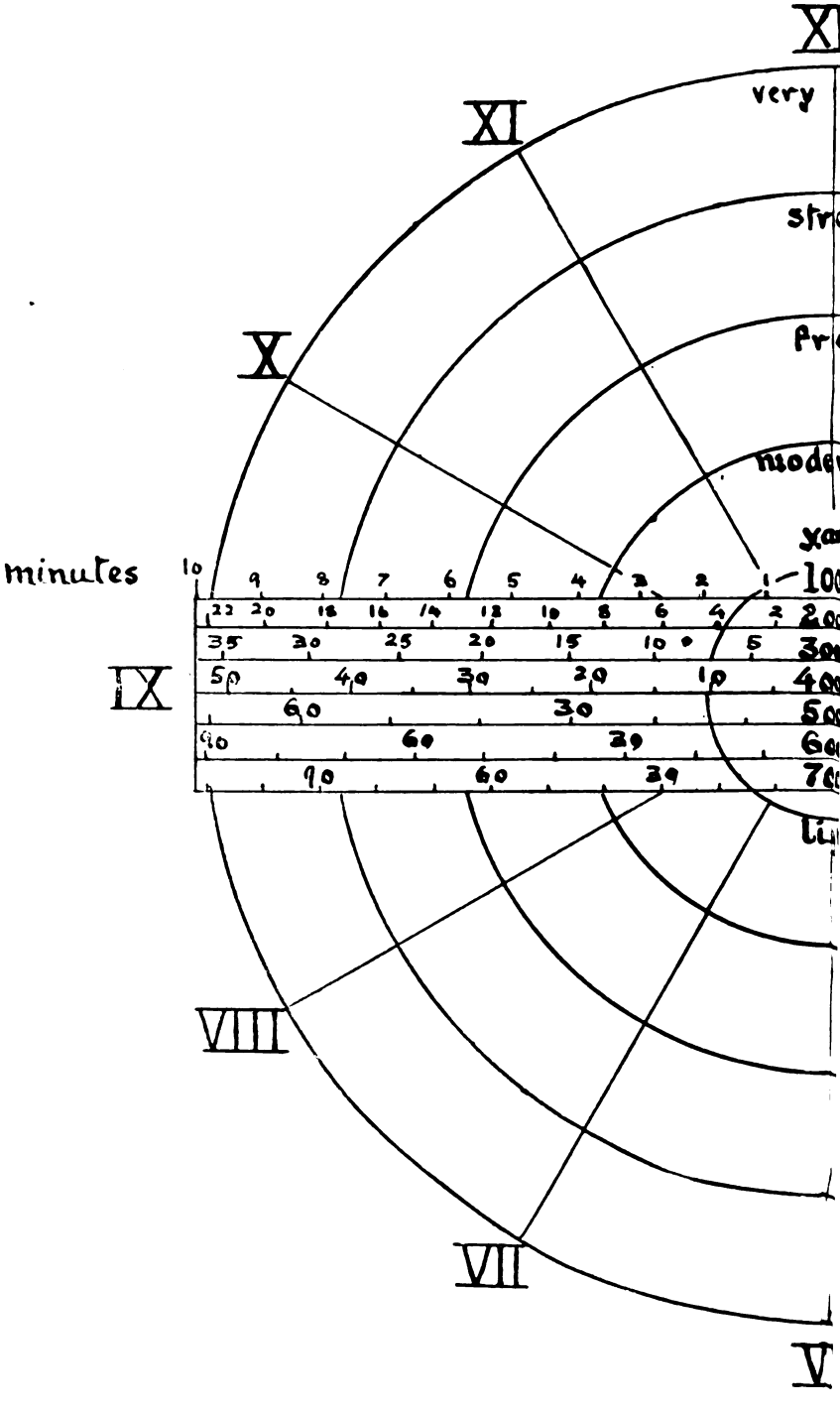

CAPTAIN HARDCASTL

GRADUATED FOR A M.

To obtain the deflection required, follow the circle marked with the force
deflection on the scale ver

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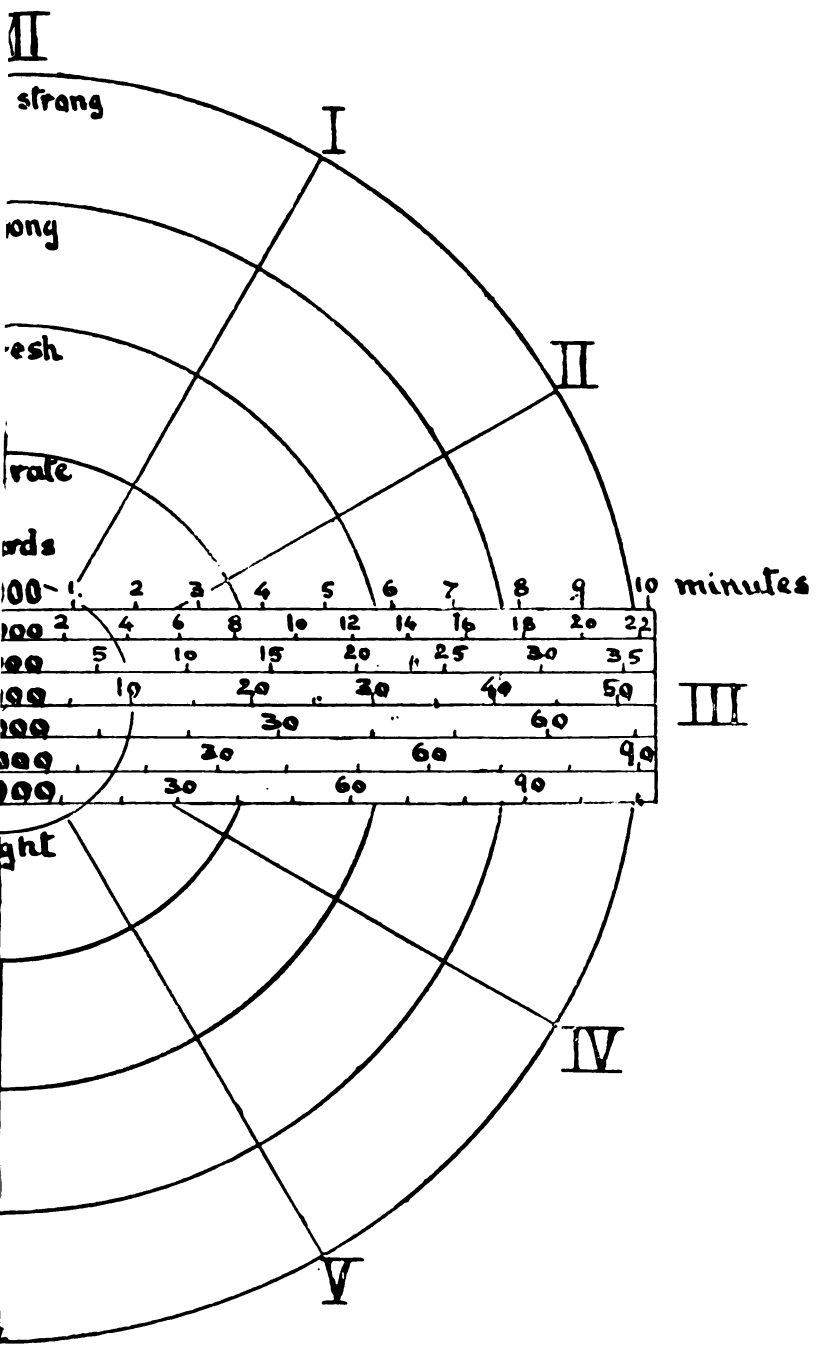

E'S WIND CHART.

DERN FIELD GUN.

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of the wind till it reaches the "o'clock" of the wind, and read off the cally under this point.

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CHAPTER XVII.

RECOIL.

The question of recoil is of extreme importance to the design of a modern field-gun. and merits careful study.

Recoil Velocity.

When a gun is fired, the shell and the gun fly in opposite directions with velocities inversely proportional to their weights; that is, if we neglect the weight of the powder, which will be considered hereafter. If a shell weighing 10 lbs. be fired from a gun weighing 1000 lbs., then if the shell starts at 1000 feet per second the gun will recoil at 10 feet per second.

Let W be the weight of the gun, w of the shell: U the recoil velocity of the gun, v the velocity of the shell.

$$\text{Then } \frac{W}{w} = \frac{v}{U}$$

Recoil Energy.

The force of the powder is expended partly in propelling the shell forwards, partly in propelling the gun backwards. If the gun weighed no more than the shell, they would fly apart with equal velocities, and the work done upon each would be equal. If the weight of the gun were infinite, it would not move at all; the work done upon it (neglecting heating) would be nil, and the whole force of the powder would be expended on the shell. This is at first sight inconsistent with the truth that action and reaction are equal and opposite. This axiom however only means that the force exerted by the powder is equal in both directions. And since the work done by a force upon a body is proportional to the distance through whith it acts, then the shell, which is acted upon for the whole length of the bore, must get more work done on it than the gun, which is only acted upon for the short distance through which it moves before the shell leaves the muzzle.

The work done upon a moving body, or the energy imparted to it (which amounts to the same thing) is expressed by the formula:

$$E = \frac{wv^2}{2g}$$

for the proof of which the student must refer to a treatise on Elementary Dynamics. Thus a 15 lb. shell travelling at 1640 fs. has stored up in it an energy of $\frac{15 \times 1640^2}{64.4} = 624{,}800$ foot pounds or $\frac{15 \times 1640^2}{64.4 \times 2240} = 279.7$ foot-tons.

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Suppose this shell fired from a gun mounted on a rigid carriage, weighing altogether 1 ton; then the recoil velocity of the gun and carriage would be $\frac{1}{2240} \times 1640$ fs. $= 10.98$ fs. and the recoil energy of the gun and carriage would be $\frac{2240 \times 10.98^2}{64.4 \times 2240} = 1.873$ foot-tons.

This would be enough to lift the gun and carriage, if stopped from recoiling, 1.873 feet into the air.

Next suppose the same shell fired with the same velocity from a modern Q.F. gun. (This would require more powder, since in this case, as will be seen, more work is done on the gun and less in proportion on the shell.) The weight of the recoiling parts, namely gun and buffer, would be about 800 lbs.; therefore the recoil velocity is now $\frac{1}{800} \times 1640 = 30.75$ fs., and the recoil energy $\frac{800 \times 30.75^2}{64.4 \times 2240}$ $= 5.365$ foot tons, or some three times as much as before.

How is it, then, that a Q.F. gun, which develops 3 times the recoil-energy of a B.L. gun, contrives to stand steady on firing? The answer is to be found in the arrangement of the buffer. As we know, a hydraulic buffer consists of a long cylinder filled with a viscous material such as glycerine or Rangoon oil.

In this cylinder works a piston, which nearly fits it. The cylinder is attached to the gun, the piston-rod to the carriage. Then on recoil the cylinder moves backwards, drawing out the piston-rod; the oil or glycerine has to pass through the narrow space or windage between piston and cylinder, opposing a strong resistance as it does so. In a well-designed buffer the windage is so adjusted, by varying the depth of the ports in the walls of the cylinder, that the resistance opposed by the liquid bears a uniform ratio to to the stability of the carriage throughout the recoil.

Now suppose that the gun and buffer recoil 4 feet before coming to a standstill. Then the recoil-energy of 5.365 tons has been expended in pulling out the piston 4 feet against a certain resistance. If we consider the resistance to be a weight, then we shall have expended 5.365 foot tons of energy in lifting that weight 4 feet; therefore the amount of the weight, or average resistance, must be $\frac{5.365}{4}$ $= 1.341$ tons.

Under the assumed conditions the effect of firing a Q.F. gun will be to produce a steady pull upon the carriage averaging 1.341 tons, acting through the line of motion of the centre of gravity of the recoiling parts. Since this force is greater than the weight of the gun and carriage, why does the carriage not overturn?

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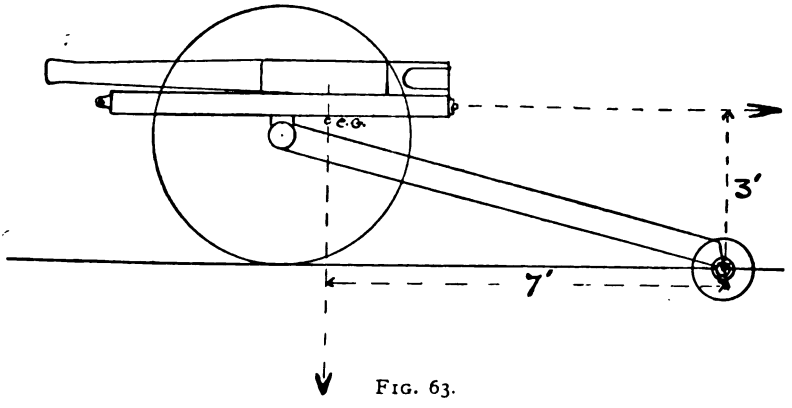

FIG. 63.

The reason will be apparent on considering the above figure. Suppose the carriage hinged to the ground at the point of the trail; then the pull of the piston-rod tends to revolve the carriage backwards about the fulcrum. The moment of the pull about the fulcrum is equal to its amount multiplied by the vertical distance of the C.G. of the recoiling parts from the fulcrum, which is about 3 feet. Similarly the weight of the gun-carriage, tending to keep the wheels on the ground, acts vertically downwards through the centre of gravity of the system, and its moment about the fulcrum is equal to the weight, about one ton, multiplied by the horizontal distance from the fulcrum—say 7 feet.

Then the overturning force of $1.341 \times 3 = 4.023$ tons is resisted by the downward force, $1 \times 7 = 7$ tons; therefore the wheels will not lift from the ground, and the carriage will remain steady.

Strictly speaking, the fulcrum should not be taken as the point of the trail, but rather as the centre of the area of the spade. In bad ground the fulcrum is still lower, since the spade then holds principally by its point.

Weight of Powder Charge.

In order to simplify the question, we have so far left out of account the weight of the powder-charge. This must however be reckoned with, as it adds materially to the recoil-energy.

In old text-books it was customary to consider the powder-charge as igniting from the middle, one half going forwards with the shell, and the other half backwards with the gun. In calculating recoil-velocities half the weight of the charge was added to the weight of the shell, the other half to the weight of the gun. This is however unsound, since the whole charge is propelled out of the gun before the latter has finished recoiling. And besides this, the explosion of the charge takes more effect upon the gun than it does upon the shell. For the forward impulse communicated to the latter by the expanding gases ceases when it has gone a yard or so from the muzzle, whereas the burning gases still continue to issue from the gun, producing a strong unbalanced pressure upon the breech, when the shell is already a hundred yards distant on its way. Accordingly

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Sebert's velocimeter (referred to in Chapter I.) shows that the maximum recoil-velocity is not attained till an appreciable time after the shell has left the muzzle.

We have then to modify our formula

$$\frac{W}{w} = \frac{v}{U}$$

$$\text{and write } \frac{W}{w + Cw'} = \frac{v}{U}$$

where w' is the weight of the charge and C is a factor varying from 1 in long guns to 2 in short ones. For ordinary Q.F. field guns we may take C as 1.5. That is, instead of reckoning merely the weight of the shell we must add 1½ times the weight of the charge of cordite or other smokeless powder.

As an example, we will calculate the recoil-velocity of the 15 pr. Q.F. gun by the amended formula.

The shell weighs 14.3 lbs., the charge 1 lb. nearly; therefore $w + 1.5 \times w' = 15.8$ lbs. The gun and buffer weigh together about 850 pounds. The muzzle velocity with ballistite is 1640 fs.

$$\text{Then recoil-velocity} = \frac{15.8}{850} \times 1640 = 30.49 \text{ fs.}$$

$$\text{Recoil energy} = \frac{850 \times 30.49^2}{64.4 \times 2240}$$
$$= 5.479 \text{ foot-tons.}$$

Similarly, for the 18 pr. Q.F. gun,

$$W = 1175 \text{ lbs. (including half weight of springs)}$$
$$w = 18.5$$
$$w' = 1.44$$

$$\text{Recoil-velocity} = \frac{18.5 + 1.44 \times 1.5}{1175} \times 1590$$
$$= 27.96 \text{ fs.}$$

$$\text{Recoil-energy} = \frac{1175 \times 27.96^2}{64.4 \times 2240}$$
$$= 6.368 \text{ foot-tons.}$$

Period of Recoil at which the Shell Leaves the Muzzle.

This is an important point, influencing the accuracy of the shooting. Taking the 15 pr. Q.F. gun, the length of the rifling is 6½ feet, and the average velocity of the shell up the bore is $\frac{1640}{2}$ or 820 fs.; therefore the shell takes $\frac{6.5}{820} = .007927$ seconds to reach the muzzle. The recoil-velocity when the shell leaves the muzzle is something less than 30.49 fs.; we may guess it at 29 fs. Then the average recoil-velocity up to the time the shell leaves the muzzly is half that or 14.5 fs. Then while the shell is travelling up the bore the gun recoils $.007927 \times 14.5 = .1141$ feet or 1.37 inches.

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Taking the 18 pr. Q.F. gun, the average velocity up the bore is $\frac{1590}{2}$ or 795 fs., therefore the shell takes $\frac{7.5}{795}$ = .00945 seconds to reach the muzzle. Taking the recoil-velocity at 28 fs., the average recoil-velocity from rest is 14 fs. Therefore while the shell is travelling up the bore the gun recoils .00945 × 14 = .1323 feet or 1.59 inches.

Therefore if we can so construct the buffer and carriage that the gun recoils smoothly for the first $1\frac{3}{4}$ inch, any subsequent jerk or vibration will not affect the shooting.

This is the real reason why the Q.F. guns shoot so much better than the old B.L. equipment.

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CHAPTER XVIII.

SHRAPNEL FIRE.

The construction of a shrapnel shell has already been described. We know that it consists of a steel envelope containing bullets, which are blown out forwards by a bursting charge, or rather driving charge, in the base of the shell when this charge is exploded by the action of the time fuze.

We will now consider what happens to the bullets when thus blown out of the envelope.

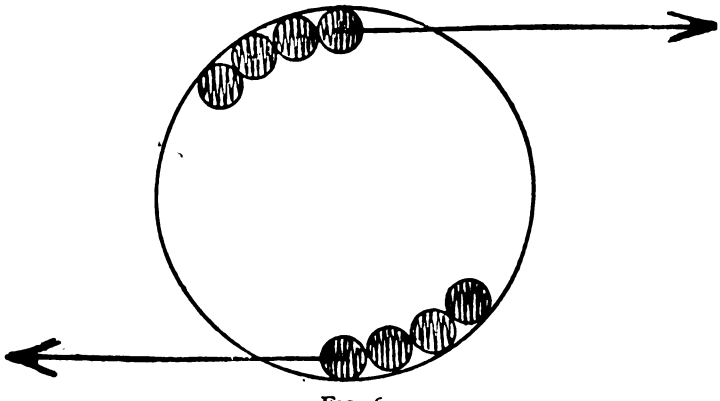

FIG. 64.

The Angle of Opening.

Take first the outer ring of bullets, namely those lying against the inner wall of the envelope. Before the shell bursts, each of these is travelling round and round the centre of the shell at a velocity determined by the twist of the rifling and the M.V. of the shell. This velocity may be calculated as follows—

Take the shrapnel of the 15 pr. B.L. gun.

Here the shell makes 1 turn in 28 calibres, or 28×3 inches, or $\frac{28 \times 3}{12}$ feet. The M.V. of the shell being 1581 feet per second, it travels 1 foot in $\frac{1}{1581}$ seconds, or $\frac{28 \times 3}{12}$ feet in $\frac{28 \times 3}{12 \times 1581}$ seconds, or $\frac{1}{223}$ second; that is, the shell makes 223 turns per second.

The velocity of rotation of the shell remains much the same to the end of its flight, since it has not to contend with the resistance of the air, but only with the surface friction while rotating in the air, which is slight. We may take the velocity of rotation of the shell at the point of burst at 220 turns per second.

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Next use the diagram of the shrapnel shell in the official handbook, and measure the distance of the centre of one of the outer bullets from the centre of the shell; we find that the distance is a trifle under one inch, and that the circumference of the circle passing through the centres of the outer bullets is 6 inches exactly.

Therefore, as the shell rotates, each bullet travels a distance of 6 inches 220 times per second, or 110 feet per second.

If now the bullets be suddenly released from the containing envelope, it is clear that in the figure (in which the shell is looked at from behind) the top bullet will fly in the direction of the arrow with a velocity of 110 feet per second, and similarly for the rest of the bullets in the outer ring. This velocity is called the *tangential* or *centrifugal* velocity.

But the bullets, and the envelope containing them, are also travelling forwards at a rate varying with the range.

For 3000 yards, for instance, we find from the range table that the remaining velocity is 831 feet per second.

To this velocity we may add the forward velocity due to the bursting charge of 1½ oz. of R.F.G. (rifle fine grained powder) which blows the bullets forward out of the envelope.

This velocity is found by experiment to average about 100 feet per second.

We may take it, then, that at the instant of burst, each bullet is travelling forwards at the rate of 931 feet per second. At the end of one second after burst the top bullet in the drawing will have flown (neglecting for the present the resistance of the air) 931 feet forward and 110 feet to the right; the bottom bullet will have flown 931 feet forward and 110 feet to the left.

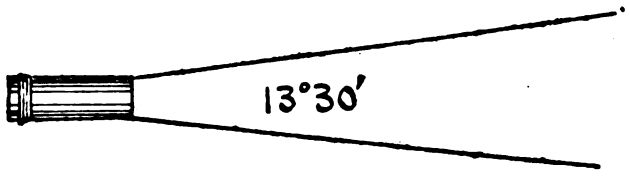

FIG. 65.

The angle between the directions taken by the outermost bullets is called the *angle of opening*. In the above instance it is 13° 30′, or about 1 in 4¼.

Distribution of Bullets.

So far we have not taken into account the inner bullets of the shrapnel shell. It is evident, however, that the centrifugal velocity of the inner bullets must be less than that of the outer ones, while the forward velocity is the same. The inner bullets will therefore diverge at a less angle than the outer ones, and will all fall within the cone formed by the outer bullets. The exact distribution of the bullets is governed to a great extent by the details of the interior arrangements of the shell, such as the shape of the diaphragm; and it is the object of the designer of ammunition, like that of the gun-maker, to get as good a "pattern" as possible.

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Air Resistance.

In calculating the angle of opening it has been assumed that the velocity of the bullets remains equal to the remaining velocity of the shell (plus that due to the forward impulse of the burster) up to the end of the first second.

But although this is not the case, the velocity being reduced by the resistance of the air, this reduction does not affect the angle of opening. For each bullet assumes its new direction as soon as it issues from the shell, and the resistance of the air is opposite to this new direction, and does not tend to make the bullet deviate from the straight line. The effect of the air-resistance is therefore to shorten the cone without affecting its angle. At the end of the first second the bullet will therefore not have travelled 931 feet forward and 110 feet sideways, but 650 feet forward and 77 feet sideways.

Effect of Range upon Angle of Opening.

As the range increases, the forward velocity of the shell rapidly diminishes in consequence of the resistance of the air. But the spinning motion of the shell, as above explained, has no resistance to overcome, except that of the circumferential friction of the air, and remains almost the same as at starting. That is to say that at long ranges the forward velocity of the bullets will be much diminished, while the centrifugal velocity remains almost as great as before.

For instance, at a range of 5000 yards the velocity of the 15 pr. B.L. shell is only 693 fs.; add 100 fs. for the burster and we have 793 fs. as the forward velocity of the bullets, while the centrifugal velocity of the outer bullets is 110 fs. as before. This gives an angle of opening of 1 in 3.6, or 16 degrees, as against 13° 30′ for 3000 yards.

Minimum Angle of Opening.

The angle of 13° 30′ above determined is the minimum angle which the bullets of this shrapnel can assume under the conditions stated. It may easily happen, however, that this angle is exceeded. This may happen owing to the bullets colliding among themselves and rebounding outwards,* and owing to the lateral expansion of the burning gases which issue with the bullets from the shell. This latter action is especially marked if the central tube is burst or torn from the diaphragm on explosion, allowing the gases from the charge to penetrate into the centre of the mass of bullets. The smoke-producing charge, consisting usually of coarse black powder introduced among the bullets, also helps to increase the dispersion.

The effect of these various disturbing factors is not easy to determine. But in practice we may take it that they increase the angle of opening by about 20 per cent.

This would make the angle of opening of the 15 pr. B.L. shrapnel at 3000 yards about 16 degrees.

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* NOTE.—In Messrs. Krupp's experiments with armour-piercing steel shrapnel bullets it was found that, owing to the elastic rebound of the bullets, the angle of opening was from 2 to 3 degrees greater than that obtained with mixed metal bullets.

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The Bullet-Cage.

For reasons which will presently be apparent, this angle was considered too large by the authorities, and a cage of perforated tinplate (in the earlier marks, of wire) was added to keep the bullets together. The effect of the cage is difficult to estimate theoretically. But in practice it may be taken as reducing the angle of opening of 15 pr. B.L. shrapnel at 3000 yards to 14°, or 1 in 4.

Profile of Bullet-Cone.

We can now draw the profile of the cone of bullets. The angle of descent of the shell at 3000 yards is 9° 4′, or 1 in 6¼. Remembering that a bullet under the influence of gravity falls 16 feet in the first second, and 64 feet to the end of the next, we take the axis of the cone as curving 16 feet downwards to the end of the first second, and 64 feet downwards to the end of the next.

(See DIAGRAM A, FIG. 66.)

This diagram is of great importance in gunnery, and merits careful examination. Before studying it, two other points must be gone into.

In the first place, except at short range, shrapnel bullets are useless after ricochet. Their velocity is low even at starting, and after striking the ground they rise at a sharp angle. When they come down again they are travelling so slowly as to be harmless.

In the next place, a shrapnel bullet ceases to be effective against a man or horse when its velocity is reduced below a certain point. The minimum velocity is dependent on the size of the bullet, a large bullet requiring less velocity to make it effective than a small one. The determination of the minimum weight and velocity is an important matter, and will be treated of in a separate chapter.

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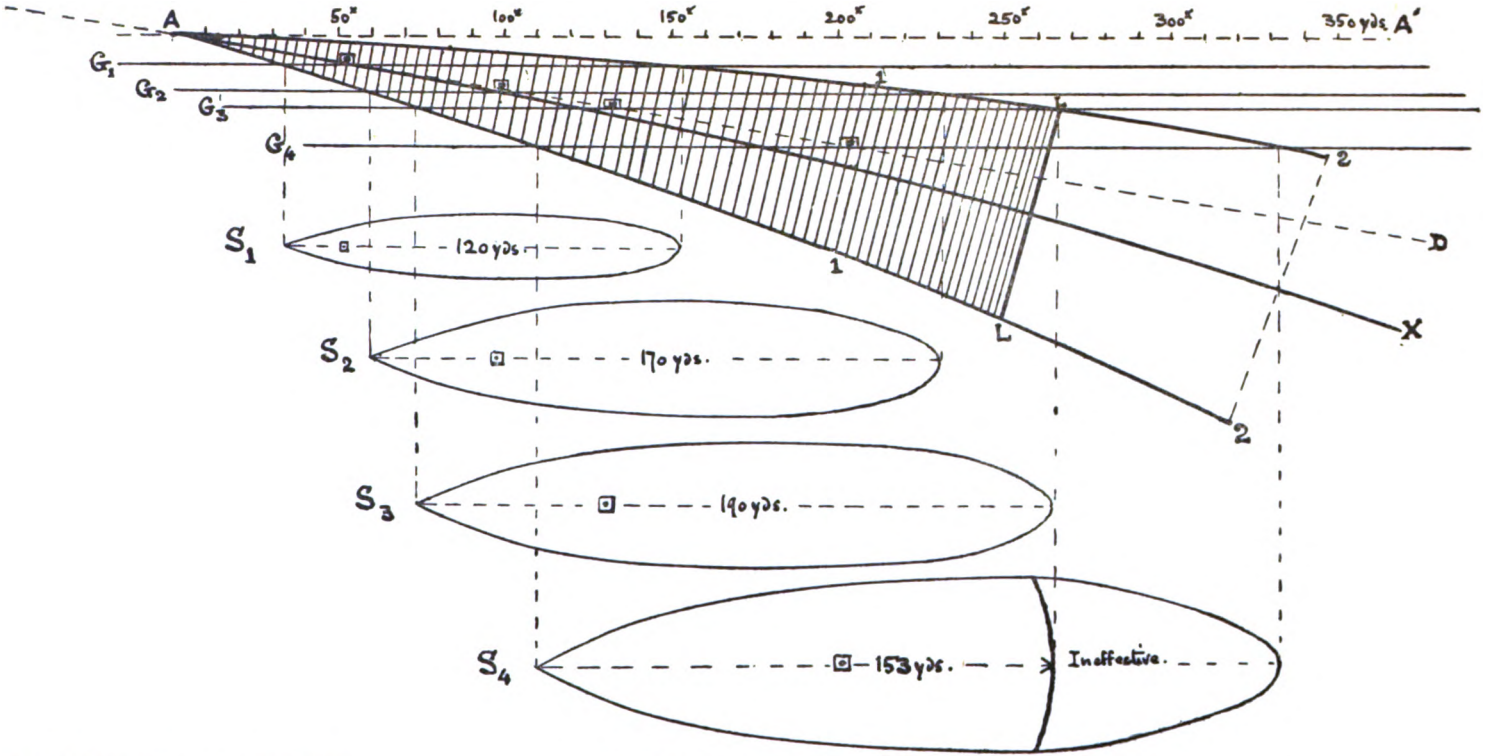

EXPLANATION OF FIGURE. **DIAGRAM A.**—Fig. 66.

The upper figure represents the cone of bullets of the 15 pr. B.L. shrapnel at a range of 3000 yards, seen from the side of the range.

AA′ is a horizontal line. A 1-1 is the cone up to the end of first second. A 2-2 the cone up to the end of the next second. LL is the limit of effective velocity, beyond which the bullets are harmless.

AX is the path of the central bullet of the cone.

AD is the prolongation of the path of the shell before bursting, descending at an angle of 1 in $6\frac{1}{4}$.

G_1 is the ground surface, drawn $\frac{3}{1000}$ or 27 feet below A, the point of burst; G_2 is the ground surface drawn 50 feet below A; G_3 is 65 feet below A, the limit at which all bullets are still effective; G_4 is 100 feet below A.

S_1 S_2 S_3 S_4 represent in plan the beaten ground corresponding to each of the above heights of burst; that is, the section of the cone by the surface of the ground.

The weight of the bullets is taken at 42 to the pound.

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CHAPTER XIX.

SHRAPNEL FIRE.—(CONTINUED).

WEIGHT OF SHRAPNEL BULLETS.

Disabling Energy.

For any given remaining velocity, the minimum weight of a bullet is that which is sufficient to produce a disabling wound upon man or horse. It is desirable to have the bullets as small as possible, in order that we may pack the greatest possible number into a shell. We must therefore so adjust the weight of the bullet that at the longest range at which the gun is to be used, and at a distance from the point of burst sufficient to cover inevitable errors in ranging, the weight and velocity of the bullet, taken together, will suffice to render it an effective projectile.

Stopping Power.

The most convenient way to estimate this "stopping power" of a bullet is by means of its energy, or the power stored up in it. This, as we know, is equal to the weight of the bullet multiplied by the square of its velocity, and is expressed in the familiar formula

$$E = \frac{wv^2}{2g}$$

Now the energy of a bullet is, from the point of view of the man hit, by no means an infallible measure of its disabling effect. Thus a large bullet travelling comparatively slowly would probably do more damage to a man than a small one flying at a high velocity. Still, as between bullets which do not differ much in weight, the striking energy may be taken as a rough basis of comparison.

German and English Estimates.

The minimum disabling striking energy is a matter of more or less empirical estimate. Experiments carried out in Germany have led to its being fixed by German writers at 58lbs. In England we prefer a slightly higher energy, possibly in consequence of the greater vitality of the uncivilized enemies against whom we are accustomed to use our shrapnel. Taking into consideration the fact that the average conscript is only too glad of an excuse to be carried to the rear by two comrades, we shall probably be safe in fixing the minimum disabling energy of a shrapnel bullet at 60 foot-pounds.

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Effective Distance.

Next we consider the distance from the point of burst at which the bullet is required to be effective. We can hardly expect a bullet to be effective at a quarter of a mile from the point of burst at extreme ranges of 6000 yards or so. Even if such a bullet were introduced, its energy would be wasted, since the angle of descent at such a range is so sharp that the central bullets of the cone strike the ground at a distance less than double the height of burst, while even the upper bullets of the cone do not ordinarily carry more than 100 yards.

Suppose, then, that we take 3500 yards as our ordinary artillery distance—and we should only rarely get a longer range in an enclosed country—and 300 yards as a distance from point of burst sufficient to cover ranging errors and to sweep a fair depth of ground behind the target.

At this range the remaining velocity of a modern Q.F. shrapnel is about 900 fs. To this we may add 100 fs. for the forward impulse given by the bursting charge, so that the bullets start with the velocity of 1000 fs. Theoretically the forward impulse should be greater, and so it is in the case of the rear bullets, which get the full force of the charge. The front bullets, however, escape centrifugally beyond the edges of the shrapnel body before the full force of the burster is developed, so that in practice we cannot reckon on an average impulse of more than 100 fs.

Starting with a velocity of 1000 fs. we have then to determine the minimum weight of the bullets so as to have an energy of 60 foot-pounds remaining at 300 yards.

Ballistic Coefficient of Bullets.

Here the problem is complicated by the relative weight and size of the bullets, which constitute their *ballistic coefficient.* It is plainly desirable to have the bullets as dense as possible, in order that their diameter may be small and that they may meet with little resistance from the air. Pure lead is the heaviest metal commercially available, but this is so soft that the bullets become flattened and distorted by the shock of discharge, spoiling their shape for flight. The lead has therefore to be alloyed with antimony to harden it, in proportions varying from 10 to 20 per cent. of antimony. The former composition, which is rather soft, has a specific gravity of 10, the latter of 9—we may take 9.5 as a fair medium.

Minimum Weight.

The direct calculation of the minimum weight from these premises is not a simple one. The easiest way is to take bullets of different weights and calculate their performance from the Gunnery Tables until we get one which satisfies the conditions.

With a starting velocity of 1000 fs. we find from the Tables that the velocity and energy of the different bullets, after flying 300 yards, are as follows:

Weight of bullet.	Remaining Velocity.	Striking Energy.
35 to the pound	395 fs.	69.2 foot-pounds
38 „ „	388 „	61.51 „
42 „ „	378 „	52.83 „
45 „ „	370 „	47.24 „

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If, then, we accept the assumption that at 3500 yards the bullet should have a striking energy of 60 foot-pounds 300 yards from the point of burst, it appears from the above table that the correct weight for the bullets is about 39 to the pound. The weight of 42 to the pound, which is still commonly adopted, is probably a survival from B.L. days, when 3000 yards was considered a long range for shrapnel, and when a battery expected to spend 3 or 4 minutes on careful ranging at a standing target before opening fire for effect. We employ bolder and more rapid methods now-a-days, and to carry these out successfully we must have a heavy far-reaching bullet, which does not depend for effect on the accurate adjustment of the point of burst—a refinement which will rarely be possible on service.

Swiss Shrapnel Bullets.

In this connection the experience of the Swiss Artillery with their new gun is of interest. It must be premised, however, that the conclusions they have arrived at are by no means generally endorsed.

The Swiss 1903 Q.F. equipment has a M.V. of 1590 fs. with a 14lb. shell, giving only moderate remaining velocities at medium ranges. The original shrapnel manufactured for the gun contained 300 bullets of 43 to the pound. These were found deficient in range and penetration, and a new shrapnel was made for the Swiss Govt. by Messrs. Krupp, containing 255 bullets of 12½ grammes or 36.3 to the pound. But the Swiss Artillery are now inclined to go even further in increasing the individual efficiency of bullets at the expense of their number. Trials have been carried out with two new patterns of shrapnel, manufactured at Thoune, in Switzerland. No. 1 contains only 210 12½ gramme bullets, with a driving charge of 2¾ oz.; No. 2 contains 215 bullets, also of 36.3 to the pound, with a driving charge of no less than 3½ oz. of powder. This latter pattern has now been finally adopted. The Swiss artillerists evidently lean rather towards French than towards German methods, and their object seems to be to obtain a bullet-swept area not far short of that given by the heavier and more powerful French Q.F. gun. Provided that their No. 2 shrapnel with 3½ oz. driving charge gives a good pattern, the sacrifice of 85 bullets out of 300 may possibly be warranted by the greatly increased area of beaten ground.

Special Bullets.

In spite of the above practical considerations, designers of ammunition are strongly tempted to increase the number of bullets in the shrapnel even at the expense of their individual efficiency. With a view to reconciling the antagonistic conditions of the problem, attempts are constantly being made to increase the density of the bullets, so as to produce a small bullet, heavy for its size, which will keep up its velocity and so be effective at the same distance as a larger one of lighter metal. Tungsten or Wolfram has been frequently proposed for this purpose—it has a specific gravity 64 per cent. greater than lead. It has not, however, been produced as a homogeneous metal, and would have to be used in the shape of a powder enclosed in steel capsules. Moreover the supply at present available

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is so small as to render its extensive employment practically impossible. An alloy of lead and mercury is heavier than pure lead, but is expensive and softer than the ordinary antimony alloy. The only practical way of increasing the density of bullets at present known is to form them by compression in a machine from a rod of metal, in the same way that rifle bullets are made. This gives an increase of density of some 3 per cent. over the cast bullets.

Pressing-in Bullets.

One way of getting more bullets into a shell, without reducing their size, is to press them together before introducing the resin which fills up the interstices. The pressure is repeated three times during the filling of the shell, a dead-weight pressure of 10 tons being employed. This has the effect of pressing small facets on the bullets where they touch, and so possibly slightly increases the resistance which they offer to the air in flight. On the whole, however, the balance of efficiency would seem to be in favour of the pressing system.

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CHAPTER XX.

SHRAPNEL FIRE.—(CONTINUED).

THE BULLET-CONE.

In Chapter XVIII. we have discussed the angle of opening, and have seen that this is dependent on the twist of the rifling and on the remaining velocity of the shell—or rather, on the initial velocity of the bullets. In Chapter XIX. we have shown that the distance to which these bullets carry, before losing their effective velocity, depends upon their weight. And in Chapter XII. we have demonstrated that the angle of descent of the shell—that is, the original direction of the axis of the cone—is determined by the muzzle velocity and the ballistic coefficient.

We will now proceed to investigate the effect of these different properties—namely, inclination, angular opening, and energy—upon the man-killing efficiency of the cone.

Bullet Cone of Freuch Shrapnel.

As a good example of a shrapnel, we will take the French shrapnel, burst at a range of 3000 yards at the "hauteur type" or $\frac{8}{1000}$ of the range.

The calculation for determining the angle of descent and remaining velocity at 3000 yards of this shrapnel is given in Example 2, following Chapter XIV. The results arrived at are—

Remaining velocity 1032 fs.

Angle of descent 5° 50′, or 1 in 10.

To determine the angle of opening we require to know the twist of the rifling. No definite information about the rifling of the French gun has been published; but we shall probably be not very far wrong in taking it at the same as used in most modern Continental guns, namely, 1 in 25 calibres. Then since the shell makes one turn in 2.95×25 inches or 6.146 feet, then, the muzzle velocity being 1740 feet, it makes $\frac{1740}{6.146} = 269.5$ turns per second.

The diameter of the outer ring of bullets is probably about the same as in the English 3″ shrapnel, namely a trifle under two inches, giving a circumference of 6 inches, or half a foot. Then each bullet travels a distance of half a foot round the centre at each turn, making 134.8 feet per second. Allowing for a slight reduction in the velocity of the rotation due to the friction of the air, we may take the tangential velocity at 3000 yards as 130 feet per second.

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Allowing for an increase of 100 fs. in the velocity of the bullets due to the base burster, then each bullet of the outer ring has, when the shell opens, a forward velocity of 1132 fs. and an outward velocity of 130 fs. That is, the tangent of the semi-angle of opening is $\frac{130}{1132} =$ .1147; the semi-angle is 6° 33′, and the angle of opening 13° 6′ This being the minimum theoretical angle of opening, we may add some 3 degrees to get the practical angle, giving about 16 degrees.

We can now draw the cone, allowing for a drop in the trajectory of the centre bullet of 16 feet to the end of the first second and 64 feet to the end of the next second.

(See DIAGRAM B. FIG. 67.)

On examining the diagram of the cone, and comparing it with that of the old 15 pr. B.L. cone illustrated in Fig. 66, we note several points of importance.

Length of the Cone.

Owing to the high remaining velocity and to the comparatively heavy bullet of 38 to the pound, the bullets at this range carry up to 330 yards or 300 metres nearly before losing their effective velocity. This is of great importance in connection with the French system of searching "registered" areas with time shrapnel.

Angle of Descent.

The high velocity gives a very flat trajectory with an angle of descent at 3000 yards of only 1 in 10. The effect of this small angle of descent is to keep the upper bullets of the cone off the ground till they have exhausted their effective velocity, thus giving a large area swept by effective bullets, utilising the energy of the bullets to the best advantage instead of dropping them into the ground while still travelling fast enough to be effective.

Angle of Opening.

It will be observed that the bullets at the extreme top of the cone are ineffective at this range, as they do not descend to within 6 feet of the ground till they have lost their effective velocity. To obtain the maximum number of useful bullets the semi-angle of opening should not greatly exceed the angle of descent.

Distribution of Bullets.

Provided that the trajectory passes through the foot of the target, then the axis of the cone must fall short of the target, and more than half of the bullets will pitch in the small portion of the ellipse in front of the target. Over the rest of the beaten ground the proportion of bullets per square yard decreases with the distance from the target till at 330 yards the only effective bullets are those in the small segment of the circular section of the bullet-cone cut off by the ground-line, as in Fig. 67, E. Even from these must be deducted the number which do not fall within 6 feet of the ground before losing their effective velocity. From this we learn that it is not sufficient to trust to the depth of the bullet-cone to sweep the ground

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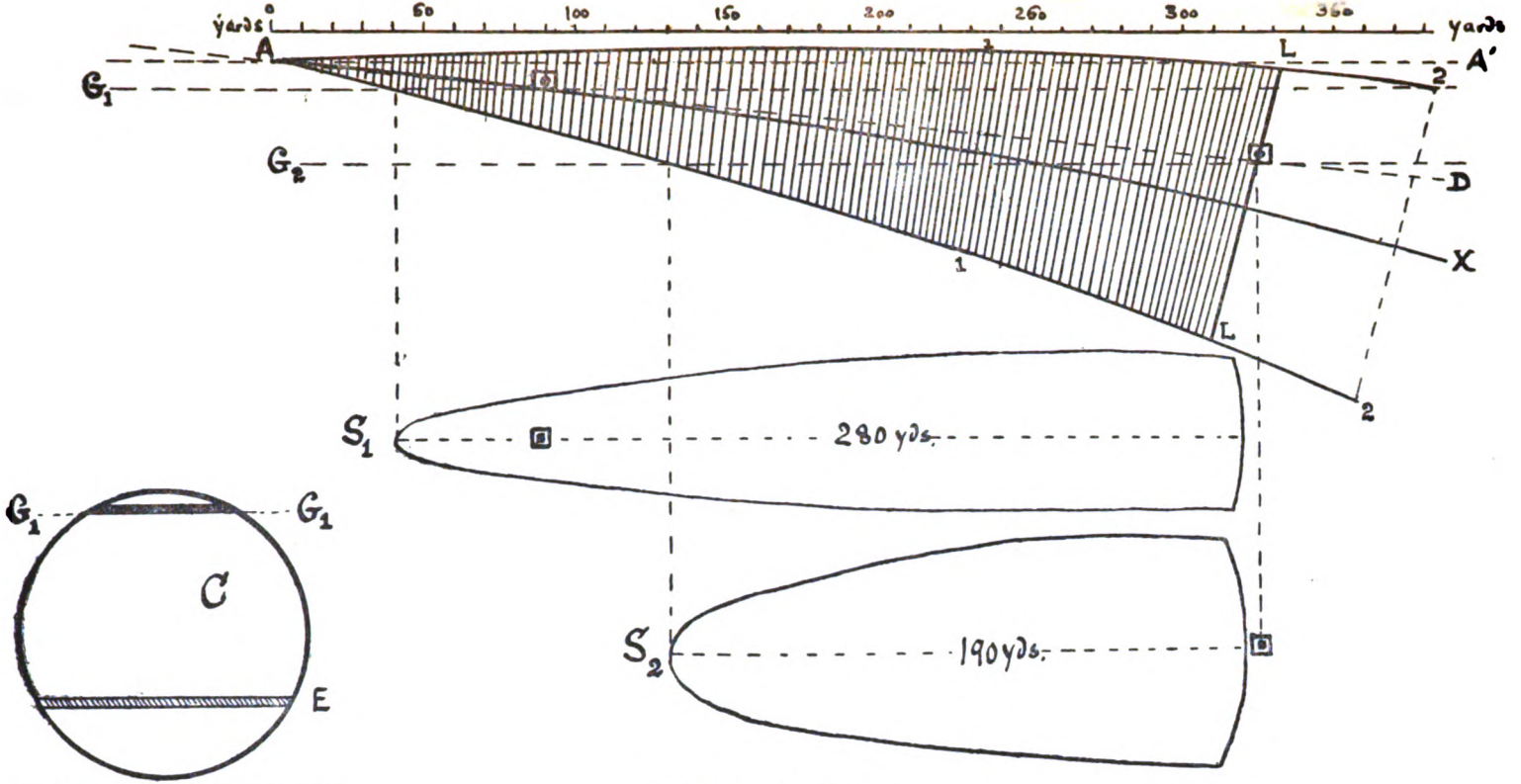

EXPLANATION OF FIGURE.

DIAGRAM B.—FIG. 67.

The upper figure represents the cone of bullets of the French Q.F. field shrapnel at a range of 3000 yards, seen from the side of the range.

AA′ is a horizontal line. A 1-1 is the cone up to the end of the first second, A 2-2 is the cone up to the end of the next second. LL is the limit of effective velocity, beyond which the bullets are harmless.

AX is the path of the central bullet of the cone.

AD is the prolongation of the path of the shell before bursting, descending at an angle of 1 in 10.

G_1 is the ground surface drawn $\frac{3}{1000}$ or 27 feet below A; G_2 is 100 feet below A.

S_1 S_2 represent in plan the beaten ground corresponding to each of the above heights of burst; that is, the section of the cone by the surface of the ground.

The weight of the bullets is taken at 38 to the pound.

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thoroughly. Even when the range is correctly found at least half of the bullets must be short and therefore ineffective. For shrapnel bullets do not ricochet to any useful purpose; owing to their spherical shape they rise sharply after graze, and when they come down again they are travelling so slowly as to be harmless. And supposing that the range is not correctly found, but is short of the target, then the number of bullets striking in the portion of the ellipse at and beyond the target will be only a small fraction of the whole.

Raising the Trajectory.

Supposing that the trajectory be raised by increasing the elevation without altering the fuze, then the distribution in depth will be improved, a larger number of bullets pitching over the target. This proceeding is occasionally permissible, as when the target consists not of a line of troops, but of troops scattered over a deep area of ground. This is equivalent to ranging not on the near side of the target but on a point beyond the edge, and then using a short fuze. But when the principal portion of the target is the front edge or front line of troops, this method is inadmissible. For the trajectories of a number of shrapnel shell fired at a target do not coincide, but form a sheaf of fire, some being over and some short. If the mean trajectory passes through the front line of the target then the half which (if they did not burst) would pitch over are wasted, or nearly so, as far as the front line is concerned, and only the shorter half of the sheaf can be reckoned on for effect. And if we raise the trajectory so that three-quarters would pitch over, then the only shell effective on the front line will be the remaining quarter, which, if they did not burst, would pitch at the target or short of it.

Further, raising the trajectory reduces the width of the front line of the target covered. Taking the target as a six-foot (or three-foot) zone drawn across the circular section of the bullet-cone, as in E, Fig. 67, then the number of bullets intercepted by the six-foot zone will be greatest when its centre coincides with the centre of the circle, and will decrease as the centre of the circle is raised above the target.

Density.

The question of the density of the bullet-cone in relation to the area of each individual unit of target is discussed in the chapter on Ranging.

The Angle of Descent.

This has already been referred to on page 138. But the practical effect of a small angle of descent will be more clearly seen on comparing the diagram of the shrapnel cones of the 15 pr. B.L. and the French gun.

In spite of the higher velocity and heavier bullet of the latter, the difference in the length of the cone is not very marked, the distances at which the bullets are effective being 330 yards and 280 yards respectively. This is due to the rapid falling-off in velocity of shrapnel bullets, most of the extra initial velocity being soon expended in

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overcoming the resistance of the air. But on comparing the depth of "beaten ground" we find that when both the shell are burst at the typical height, $\frac{3}{1000}$ of the range, the French shrapnel covers 280 yards in depth as against 120 yards for the 15 pounder B.L This astonishing discrepancy is principally due to the difference in the angles of descent, which are 1 in 10 and 1 in 6½ respectively. This comparison is however unfair to the 15 pr., as a better figure is obtained by bursting its shell 50 feet high instead of 27. But even in this case the depth is only 170 yards as compared with the French 280.

High versus Low Velocity.

In the French gun the angle of descent is flat enough to carry at least the top bullets of the shrapnel cone to the limit of their effective velocity before they strike the ground, whereas the 15 pr. bullets are stopped with much of their effective velocity unexpended. And this leads us to a most important modern question, namely high versus low velocity. From a gun of given power and calibre we may either fire a heavy shell with a curved trajectory, or a light shell, like an express bullet, with a flat one. In the former case we get a large number of bullets, in the latter a small number; in the low-velocity gun we get more remaining energy in proportion to the strain on the gun, while in the other the high velocity soon dies away owing to the increased air-resistance and to the want of staying power of the light shell.

What, then, do we gain by increasing velocity at the expense of shell-power?

We secure a small angle of descent, giving a deep dangerous zone and far-reaching shrapnel bullets. We facilitate ranging and minimize the effect of errors in range and fuze. And at deep targets we get a better distribution of bullets over the beaten area.

As against this, we lose a percentage of bullets proportional to the reduced weight of the shell. Say we lose 30 per cent. of bullets, we shall have to put 30 per cent. more guns in line to produce a given effect *in the same time*. This means 30 per cent. more men and horses, and 30 per cent. more casualties.

Light versus Heavy Shell.

The effect of increasing velocity and reducing weight of shell will be best seen by comparing two extreme instances. Take a gun firing a 20lb. shell with a M.V. of 1500 fs. The muzzle energy is $\frac{20 \times 1500^2}{2g \times 2240}$ or 312 foot-tons. Take another gun of the same calibre with a M.V. of 2000 fs., firing a shell of 11¼ lbs. The muzzle energy is 312 foot-tons, the same as before, and the gun and carriage will be of the same weight as in the first case. That is, we shall have sacrificed 43.75 per cent. of bullets to get the extra 500 fs. velocity. In this case it is evident that the gain is not worth the sacrifice.

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Correct Proportion of Weight to Velocity.

The muzzle energy given above, namely, 312 foot-tons, may be considered about the average for a Q.F. field-gun weighing 22 cwt. in action. This being the product of the weight of the shell and the square of its velocity, we have to decide on the best proportional value of these factors. Unfortunately this is not a matter of exact science, but a question of tactics. For deliberate shooting at a standing target the powerful shell is to be preferred; for rapid shooting at a scattered or moving target the flat trajectory and far-reaching bullet-cone will give better results. The latest examples of gun-construction show values between the two extremes quoted above, the American 1904 gun, for instance, having a shell weighing 15 pounds (not 14.3) with a M.V. of 1700 fs., and a muzzle energy of 300 tons.

Searching Power with Flat Trajectory.

It is sometimes urged as an objection to high-velocity guns that the trajectory is so flat as to pass clear over a crest line without searching the reverse slope. This statement however will not stand the test of arithmetic. For however flat the trajectory we shall hardly get an angle of descent of less than 5° at medium ranges, and few reverse slopes so steep as this are to be met with on service. And if we add to the angle of descent the semi-angle of opening, between 7 and 8 degrees, we get a "searching angle" of 12° to 13°, which corresponds to a slope which men would have to climb almost on their hands and knees. The maximum searching power is obtained when the angle of descent is equal to the mean reverse slope—say from 2 to 3 degrees, according to the country—and the flatter the trajectory the nearer we approach to this ideal.

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Part III.

PRACTICAL GUNNERY.

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CHAPTER XXI.

PRACTICAL GUNNERY.

The Choice of a Position.

A position is selected principally on tactical grounds which are outside the scope of this book. Regard should however be had as far as possible to considerations affecting the shooting of the guns.

Quick firing guns are much longer in the trail than B.L. guns, and have a less range of elevation and depression available. It is most desirable that they should stand on firm and level ground, free from large stones.

Unless the ground is firm the spade will not take hold properly, and the gun will tend to move sideways during firing.

If the ground slopes down to the front it is often impossible to get sufficient elevation, especially when (as is frequently the case in hilly country) the target is above the gun.

If the gun be on a steep reverse slope, firing at a low angle of elevation, then the axis of the piece will make a large angle with the trail and the gun will jump instead of remaining steady on firing.

Large boulders in the ground prevent the spade from taking a fair bearing, and make the gun exceedingly difficult to traverse.

Whenever the ground is bad, it will be found to save time if the section commanders and layers are fallen out before coming into action to select emplacements for their guns.

Since guns must have a good view of the battlefield, they are usually posted on high ground. The choice of position, for direct fire, will as a rule lie between the forward crest and the rear crest.

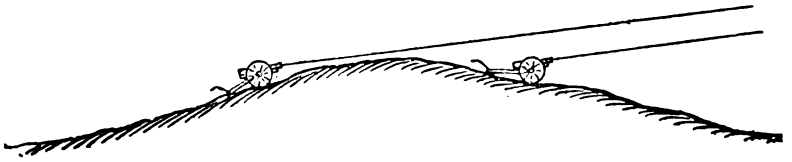

Fig. 68.

The forward crest position gives a better view, and the guns, being below the sky-line, are difficult for the enemy to locate, so long as the men keep still. There is a position on Salisbury Plain with a low irregular gorse-covert behind the guns, which are fully exposed to view in front of it. A battery in this position is most difficult to make out, provided that its fire discipline is good and that there is no unnecessary running about.

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On the other hand, the forward position renders ammunition supply difficult. And with a quick-firing gun, which has a long trail with a large spade at the end of it, it is often impossible, on a forward slope, to get sufficient elevation for the first round without digging in the spade. When this happens it is sometimes advisable to fire off the ranging section guns with as much elevation as can be got, even if insufficient to reach the target. This will bury the spades and give another two or three degrees of elevation.

As a rule, the forward crest position makes it easier for the enemy to range, since *plus* rounds can be observed.

The rear crest position has the serious drawback that the guns must stand up above the sky-line, and also that the field of view is inferior to that obtained from the forward crest. The former disadvantage may be minimised by keeping the guns run back till required to open fire; the latter, by keeping look-out men with glasses in front of each flank.

Cover for Limbers and Wagons.

The slope of descent of a field shell at 3000 yards is about 1 in 6; that of the lower bullets of a shrapnel is about 1 in 5. Now a hill with a slope as steep as 1 in 5 from top to bottom is rarely to be met with. It follows that it is practically impossible to obtain cover for the limbers and wagons by posting them at the foot of the hill close behind the guns.

Since many of the shell fired at the guns will burst quite 200 yards over, and since shrapnel bullets are effective 300 yards beyond the point of burst, it follows that the line of limbers and teams must be *at least* 500 yards in rear of the guns, or still further if the range is a short one. It is sufficiently obvious that it is not desirable to place the limbers and teams directly behind the battery if this can be avoided.

FIELD ENTRENCHMENTS.

This question will only be touched upon in so far as gunnery questions are involved.

In entrenching a gun, the first thing to see to is that the gun can be turned upon any target which it may be required to fire upon. If an embrasure is used, the space inside the gun-pit or entrenchment must therefore be large enough to allow full traverse for the gun.

Protection for the detachment is the next consideration. This is best provided by digging deep trenches on either side of the gun, in which the men, when not actually serving the gun, can sit with their backs to the parapet, their heads being at least a foot below the crest, which must be thick and solid. It must be remembered that the angle of descent of shrapnel bullets, at medium ranges, is about 1 in 5, so that protection is only obtainable close under the parapet.

A liberal supply of ammunition must be provided for.

The best position for the gun-entrenchments is usually the forward crest; on no account must they be on the sky-line.

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Shelters for the battery commander and section commanders must be provided.

It is hardly necessary to say that gun-pits should not be so constructed as to afford targets for the enemy. When possible, they should be combined with natural features of the ground.

With ten gunners digging and three drivers cutting sods, it takes from three to four hours to provide good cover for a gun.

If dummy entrenchments are used, these should be at such a distance from the real ones that the latter will be well outside the total rectangle of shots fired at the dummies. Under service conditions, at medium ranges, the total rectangle may be taken at 500 yards × 100 yards.

Concealment of Flash.

Practical experience shews that the broad white flash from the muzzle of a field gun firing smokeless powder is visible when the gun is behind cover, unless the muzzle is at least ten feet below the covering crest. This means that the gun must be placed at a point of the reverse slope which is at least 13 feet below the crest, otherwise the enemy will be able to locate it when it opens fire.

A field howitzer firing full charge will probably require 20 feet of cover above the muzzle.

Position for Indirect Fire.

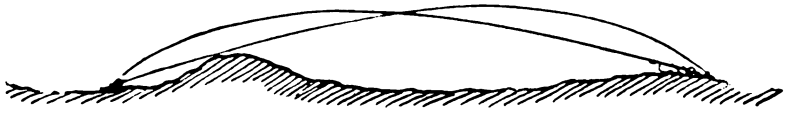

FIG. 69.

For a field gun, the angle of descent of a shell is always about one-third greater than the angle of elevation. If a battery be firing at 3600 yards, which corresponds to about 6 degrees of elevation, then the angle of descent of its shell will be 8 degrees. If, therefore, two batteries of similar guns are firing at each other, both being under cover so that their shell barely clear the covering crests, each will be able to hit the other. In other words, when engaging a hostile battery it is impossible to obtain natural cover from its fire. The advantage of the covered position is solely due to concealment from the enemy's view. It follows, therefore, that the cover afforded by trees, houses, hedges, etc., is just as good as that afforded by a rise of ground. A practical exception to this rule is that the cover must not be of such a nature as to act as a penetrable screen to burst the enemy's shrapnel within effective distance of the battery.

Forward and Retired Covered Positions.

Suppose the reverse slope of a hill to average 4°, or 1 in 15, and

FIG. 70.

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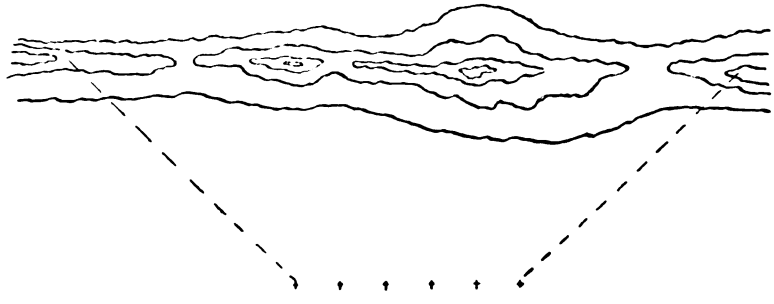
the angle of elevation, for 2500 yards, to be 3° 40′. Then to clear the crest the gun must either be posted back from the foot of the hill, or upon the more gentle slope near the top of the hill. The latter is in many ways the better position; it admits of greater quickness in taking up the position and in changing target, and easier observation; it also renders it possible to run the gun up to the "rear crest" position if required to change to direct fire. But it must be borne in mind that unless the gun is 10 feet below the crest the flash will be visible as soon as the battery opens fire, enabling the enemy to locate each gun. The forward covered position is then dangerous if the enemy's artillery is in superior force.

The rear covered position requires the crest of the hill in front of it to be kept clear for a distance equal to the front of the battery, plus a distance on either side equal to that of the battery from the crest. This is necessary in order not to infringe on the "danger angle" of 45° from the muzzles of the flank guns.



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That is, if the battery is 100 yards in rear of the crest, it will require the crest to be kept clear of other troops and other guns for 300 yards; if 200 yards in rear, the battery will require 500 yards of crest to itself. Further, if the battery commander observes from the crest he will need to be, in the latter case, 200 yards to the flank. This limitation practically precludes the use of the rear covered position except for single batteries and sections acting independently.

It is useful to bear this in mind when engaging concealed artillery. If the enemy's artillery force is known to be large, it is most improbable that he will be able to find room to post his batteries more than 100 yards in rear of a crest. By ranging on the top of the crest, and then firing at ranges increased by 25, 50, and 100 yards—say one section at each elevation—we therefore stand a good chance of producing effect.

The inference as to the distance of the enemy's guns behind the crest does not however apply to artillery using telephones or an efficient system of flag-signalling. For there is nothing to prevent all three battery commanders being with the O.C. Brigade at an observing station on the flank of the position.

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CHAPTER XXII.

THE OCCUPATION OF A POSITION.

Intervals.

A most important matter, from a gunnery point of view, is the necessity of maintaining the full interval of 20 yards between the guns.

It will be readily understood that if this interval be reduced an enemy's shrapnel may take effect upon two gun detachments instead of one, doubling the number of casualties. The mathematical calculations bearing on this point depend upon the Theory of Probabilities, and must be studied in more advanced works than the present one. But it may be pointed out that the 20-yards interval has not been accepted without good reason by all civilised nations. The practical gunner may safely take it for granted that if he halves his gun intervals he will double the number of his casualties, and so in like proportion.

On the other hand, there is no direct gain from the use of unduly wide intervals. It requires no mathematics to show that if the interval be greater than the ordinary spread of shrapnel bullets—say 30 yards—one shrapnel cannot possibly hit two guns. Guns 50 yards apart are therefore no safer than if 30 yards apart. Nor is there much to be hoped for from shrapnel passing clear between two guns without hitting either. For if widely dispersed each gun will form a separate aiming-point for the enemy, and his gunnery must be very poor if he cannot get his line within ten yards.

Method of Occupation.

The tactical details of the occupation of a position are rather beyond the scope of this book. From a gunnery point of view there are four types of position. In the first, or direct position, the layers can see and lay on the target. In the second, or semi-covered position, the guns are posted just behind the crest, so that the layers, standing erect, can see to lay for line while giving elevation by clinometer. This is the favourite French position. In the third or advanced covered position the guns are near the crest, so that an officer standing behind the gun on a limber, or on the observation ladder, can see the target and direct an aiming post to be placed in line with it.

In the fourth, or fully covered position, the guns are so far below the crest that the target cannot be seen from the neighbourhood of the guns.

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Neither the semi-covered nor the advanced covered position gives concealment from the enemy when once the guns have opened fire. For the flash of the gun is visible over the covering crest unless the muzzle is at least 10 feet vertically below it for field guns, or probably 20 feet for howitzers.

Except in the case of howitzers, which may be able to get close behind a steep covering mass, none of the four positions affords cover from the enemy's gun-fire. For, as explained above on page 147, if the shell from the battery can clear the crest the enemy's shell can also do so. Covered positions would in fact be more correctly described as concealed positions. Theoretically, therefore, the best covered position is the one best adapted to keep the enemy ignorant of the position of the battery.

This condition, as will be seen, is fulfilled only by the *retired* or *fully-covered* position. It may however be necessary on tactical grounds to use the semi-covered or the advanced covered position. These have no advantage on the score of quickness in opening fire, since a battery equipped with goniometric sights can come into action behind a hill and get its line in much less time than it would take to man-handle the guns into position on the slope near the crest. But when it is anticipated that it will be necessary to run the guns up to support or to repel an attack by direct fire, then they should usually be posted near the crest to avoid the necessity of bringing up the teams under fire.

The method of directing the fire of guns from a covered position will be dealt with in the following chapter.

Direct Occupation of a Position.

The ordinary methods of occupying a position are fully described in F.A. Training, and involve no special points of gunnery. There is however one method which is occasionally useful and merits consideration.

Suppose that a Q.F. brigade has to engage another Q.F. brigade already in position, and that on tactical grounds it is not desired to use indirect fire. Then the following method may be applied—

Run up a single gun by hand on to the position, or, preferably, to another point at the same distance from the enemy. It will usually be possible to find cover for this gun so that it will take the enemy some time to locate it. Range and find fuze with this single gun, and let the rest of the brigade load, set sights, and prepare fuzes. Then let the whole brigade come into action direct and open rapid fire at once.*

Allowing one minute for laying and pointing out target, in the second minute the brigade should be able to fire from 200 to 250 rounds of time shrapnel. The suddenness and vigour of the attack, if properly carried out, should at least neutralise the advantage enjoyed by the enemy of being already in position.

* NOTE.—I am indebted for this suggestion to Colonel Lindsay, D.S.O., R.F.A.

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SELECTION AND DISTRIBUTION OF TARGET.

In selecting the target, tactical considerations are paramount. The increased rate of fire obtainable from modern guns must, however, inevitably lead to a departure from older methods. Thus if several targets present themselves simultaneously to a battery—such as three different bodies of infantry—the maximum effect will usually be obtained by assigning one to each section. A well-trained section, after completing its ranging, should be able to fire 100 rounds of time shrapnel in five minutes. Supposing that at a favourable target, under service conditions, only one hit per shell is obtained, this still represents a considerable—probably a decisive—result. If the whole battery were turned on to one target, the other two bodies of infantry would escape for ten minutes at least, and possibly get off scot free. Opportunities of engaging favourable artillery targets are fleeting, and when such occur the Battery Commander should not hesitate to utilize the full power of his guns to take advantage of them.

Distribution of Target.

In ordinary cases the simplest and best method is for each battery and each section to engage the portion of the target opposite to it. This rule is however subject to modification.

Thus, suppose a F.A. brigade engaging a hostile F.A. brigade. The C.O. finds that his fire, though effective, is not sufficient to silence the enemy. His best course is to concentrate the fire of his whole brigade upon each of the enemy's batteries in turn.

There are two reasons why this concentrated fire is especially effective. The first is the moral effect, which is of the highest importance, but is not a matter of exact science. The second is, that while it is often possible for a man to obtain cover from bullets coming only from one direction, this is less easy when the bullets come in from three directions at once.

The period during which fire is concentrated upon one battery must not be long enough to give the other batteries time to recover and refit. Fuzes should therefore be set beforehand and "rapid fire" commenced when concentration is ordered.

Cross Fire.

At medium ranges, when observation is easy, cross fire may sometimes be employed. Thus if a F.A. brigade is engaging a line of entrenchments a quarter of a mile long at 3000 yards range, it may be advisable to order the Eastern battery to fire on the Western end of the enemy's line, and vice versâ. This is because a trench or a parapet affords less protection from oblique than from frontal fire, and none from enfilade fire. Suppose the angle of descent of shrapnel bullets 1 in 6, then a man kneeling 3 ft. 6 in. high would be safe against frontal fire if he knelt 1 yard in rear of a 4 foot parapet. But a bullet coming over the parapet at an angle of 45° from a flank would take the man $6(\sqrt{2} - 1)$ or 3.5 inches below the top of his head.

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CHAPTER XXIII.

INDIRECT FIRE.

General Remarks.

The term *indirect fire* is applied to the fire of guns or howitzers which are not layed upon the target to be attacked by direct vision.

In this nature of fire the four principal methods of directing the gun are—

1. By an auxiliary mark, usually called an *aiming point*, for line, and by clinometer for elevation.
2. By direct vision for line, and by clinometer for elevation.
3. By an aiming point both for line and elevation.
4. By direct vision for elevation and by aiming point for line.

In the French Artillery indirect fire is normally used, even if the target happens to be visible from the guns. This latter method is sometimes but rarely applied in our service.

For instance, let the target be a battery on a hillside, visible but too indistinct to lay upon for elevation, and with a well-defined sky-line above it. Then the simplest procedure will be to order the battery to lay on the sky-line, deducting from the estimated range elevation the number of degrees by which the target is below the sky-line, which is measured by the Battery Commander with his scale held vertically at arm's length. The further procedure as regards ranging and fuzing is explained in the section on the Angle of Sight.

Or again, let the target be a long trench of which a portion only is clearly visible. Then the best results will be ensured by laying all guns on the portion visible and giving such deflection as will distribute the fire over the whole trench.

But in the great majority of cases where indirect fire is used the battery will be posted behind cover so that the target cannot be seen from the guns.

Fire from Behind Cover.

As a typical case, suppose the battery in action behind a hill, trees, houses, or other cover from view. The Battery Commander is posted sufficiently far to the front to see the target, and sufficiently far to a flank to be safe from prematures from his own guns and to allow the fire of the battery to be "switched" on to any probable target without obliging him to shift his post. From this point, known as the *observing point*, the Battery Commander commands his battery, either by telephone or by semaphore code.

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The Battery Commander reaches his post about 10 minutes before the battery arrives. Before the battery opens fire, the Battery Commander has to determine the angle of sight, the range elevation, and the line; and also to calculate the deflection corrections required for each section so as to distribute the fire over the target. He should be able to complete these operations before the battery arrives, so as to enable it to open fire at once.

In many cases on service the Battery Commander will have time to calculate with deliberate accuracy the elevation and direction of his guns, so as to open fire without any error other than that due to weather variations, known as the error of the day. But these are not the typical conditions under which a battery comes into action. The Battery Commander must be able, when necessary, to form a rapid estimate of the initial elevation and direction to be given to his guns, in order to pitch his opening rounds close enough to the target to enable him at once to make the necessary corrections from actual observation. To make this rapid estimate with confidence and success it is absolutely necessary that the Battery Commander must understand the principles governing the determination of the initial angles of elevation and direction. When working with other troops, for instance, a vague guess at the displacement angle is likely to be as dangerous to friend as to foe. But if the B.C. thoroughly understands the process of measuring his angles, then this knowledge enables him not only, when necessary, to shorten the calculation by working in round numbers, but, which is more important, it teaches him which corrections may be neglected in any particular case, and which must be taken into account.

We will accordingly first discuss the theoretical considerations upon which the determination of the initial angles of elevation and direction—or, as they are styled in French, the "éléments du tir"—are based, and we will afterwards consider their practical application.

Theory of the Angle of Sight.

The use of the angle of sight in ranging a battery is a simple matter, which however is the source of more mistakes than arise over any other detail of practical gunnery.

When the battery is firing with clinometer elevation from behind cover at a target on a higher level, then the quadrant elevation which has to be given to the guns is the sum of the elevation required for the range and of the elevation of the target above the gun, or angle of sight. And when the correct elevation has been found, then the fuze corresponds, not to the corrected quadrant elevation, but to the elevation due to the range—that is, the corrected quadrant elevation less angle of sight.

For instance, suppose a 15 pr. Q.F. battery in action behind cover at a target distant about 3000 yards, and 450 feet higher than the battery. Then the angle of sight is about 3 degrees. The elevation for 3000 yards, according to the range table, is 3° 45′. This elevation would carry the shell to a point 3000 yards from the gun, and on the same level. To reach a point 3° higher we must give 3° more elevation, making 7° 45′ clinometer elevation.

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Suppose that the Battery Commander ranges as follows—

7° 30′ (—)	...	8° 10′ (+)
7° 40′ (—)	...	8° (+)

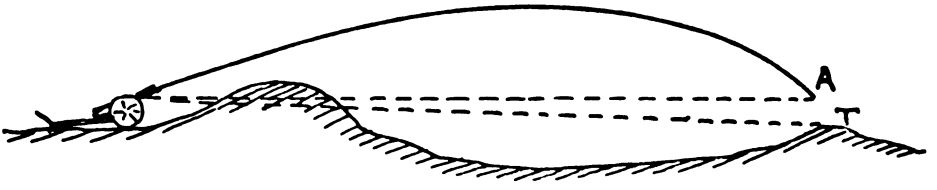
Then the probable elevation is about 7° 50′.

But 3° of this is angle of sight, and only 4° 50′ range elevation.

Fuze 4° 50′ is 7¼, therefore Battery Commander orders—

"Remainder fuze 6¼ add ¼."
"7° 50′, 2 rounds rapid fire."
(+, +, —, +.)
followed by
"7° 45′, 1 round battery fire 3 seconds."

Next suppose that the range takers give the range as 4200 yards, and that the angle of sight is 2 degrees depression, or — 2°. The elevation corresponding to 4200 yards is 7° 45′. 7° 45′ clinometer elevation would carry the shell to a point A 4200 yards distant and on a level with the gun.



To reach point T we require 2° less elevation; therefore the quadrant or clinometer elevation is 5° 45′, and the Battery Commander ranges as follows:—

5° 30′ (—)	...	6° (+)
5° 40′ (—)	...	5° 50′ (—)

Therefore the true quadrant elevation is about 5° 55′, and the elevation due to the range 2° more, or 7° 55′.

Fuze 7° 55′ being 10¾, the Battery Commander orders—

"Remainder fuze 10¼, add ¼."
"5° 55′, 2 rounds rapid fire."
(+, —, +, —.)
followed by
"5° 55′, 1 round battery fire 3 seconds."

The above examples refer to the old pattern equipment, in which clinometer elevation cannot be given on the ordinary sights. They are given here because it is necessary for the proper handling of modern sights that officers using them should understand the principle on which the design of these sights is based.

With the Q.F. sight, in which the yard scale and clinometer are combined on the same sight-bar, and with the independent line of sight, the Battery Commander is saved the trouble of adding and subtracting the angle of sight. Thus, in the first instance he would simply order "Angle of sight 3° elevation, clinometer elevation 2900, 3200," and, having found range 3100, "Remainder corrector 12, decrease one."

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The effect of the Battery Commander's order, "Angle of Sight 3° elevation," is that the adjustable level of the sight is set at 3° elevation; then when the back-sight is raised to 3100 yards, the gun has to be elevated to 3° more than the elevation for 3100 yards before the bubble of the level comes to the centre.

Aiming Points.

When a gun is layed direct at an aiming point above or below the target instead of on the target itself, the question of the angle of sight again arises.

Thus, suppose that an enemy's battery can be made out on a hill-side with glasses, but is not clear enough to lay on, and that there is a clearly defined tree on the sky-line above it. The Battery Commander measures the vertical angle between the tree and the target with the battery telescope, or with a scale held at arm's length, or simply with his knuckles. (Every officer should know the angles subtended by his own knuckles.) Now, with modern sights, his best plan would be to set the angle of sight on the adjustable sight-level and lay by clinometer elevation, using the tree only for line.

But supposing such sights not available, the Battery Commander will have to use open sights and direct laying on the aiming point.

Now suppose that the range-takers give the range as 4800, and that the aiming point is $2\frac{1}{2}$ degrees above the target. Then the mere fact of laying above the target puts on elevation, so a less amount of elevation will be required than if laying on the target. With the 15 pr. Q.F., for instance, 4800 yards corresponds to 9° 40′; take 2° 30′ from this, and we get 7° 10′, which corresponds to 4000 yards; therefore the Battery Commander opens at 3800-4200. He finds the range at 4150, which corresponds to 7° 40′; adding 2° 30′ to this he gets 10° 10′, for which the fuze is 13, corresponding to 4950 yards. He therefore orders "fuze $12\frac{1}{2}$ add $\frac{1}{2}$."

In the unusual event of an aiming point below the target being used, the Battery Commander must add the angle of sight to the elevation due to the range to get the gun angle of elevation, and subtract it again, when the range is found, to get his fuze.

The amount of arithmetic required to carry out indirect fire, or to use an aiming point, with the old-type sights is such as to render it doubtful whether these methods can be successfully applied on the battlefield. For this reason all modern field guns are fitted with clinometer sights with adjustable levels.

The Measurement of the Angle of Sight.

When a contoured map is available upon which the position of the target and of the battery can be located, the angle should be measured directly from the map. Thus, Battery $\frac{1}{4}$ of the way down the slope between the 400 and the 350 contours; target on the 600 contour distant 4500 yards. "Reduce the error to inches and divide by the number of hundreds of yards in the range;" then

$$\text{Angle} = \frac{225 \times 12}{45}$$

$$= \frac{45 \times 5 \times 12}{45}$$

$$= 60 \text{ minutes elevation.}$$

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Where no map is available, the angle of sight is measured from the observing point with the level on the telescope stand and corrected for the position of the battery.

The angle at the guns, as compared with that measured from the observing point, may be taken to be inversely as the distance from the target. Thus; Target estimated to be 3500 yards from observing point and 4000 yards from guns; angle from observing point = minus 2° 10′; then angle from battery is $\frac{2° 10' \times 3500}{4000}$

$$= 130' \times 7/8 = 112' = \text{minus } 1° 52'.$$

To this must be added the angle due to the height of the observing point above the battery. Suppose the guns 30 feet below the observing point; then with the above angle of sight the shells would pitch 30 feet below the target; therefore we require a plus correction for 30 feet at 4000 yards, that is $\frac{30 \times 12}{40} = 9'$

$$+ 9' - 1° 52' = -1° 43'$$

which is the correct angle of sight.

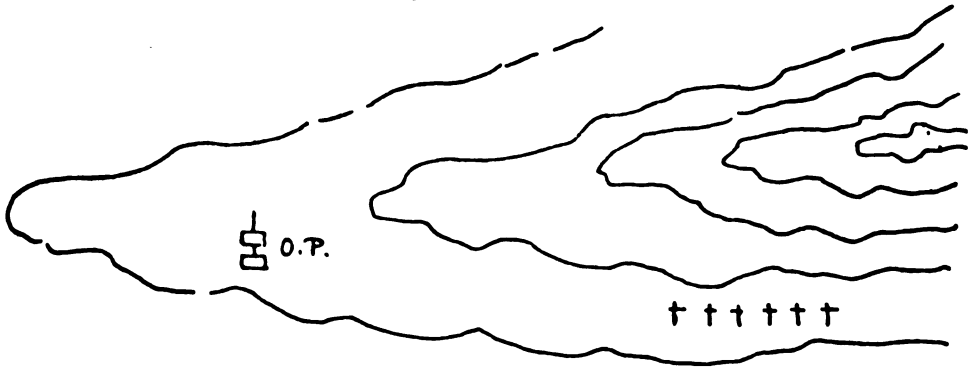
In cases where it is difficult to estimate the height of the observing point above the guns, this may be calculated.

Thus observing point is 430 yards from guns, angle of depression to guns 3°; 180 minutes = 180 inches or 15 feet at 100 yards, and 4.3 × 15 at 430; that is 65 feet. The correction must then be added for 65 feet at 4000 yards as before.

This calculation may be avoided by using Captain F. C. Tyler's Angle of Sight Table, which has been published in the R.A. Journal.

Choice of Observing Post.

Whenever possible it is desirable tc choose an observing post on the same level as the guns, in order to avoid at least one of these two corrections of the angle of sight.



Thus in the figure the Commanding Officer is posted on the shoulder of the hill, on a level with the battery and at the same distance from the target. By standing on a wagon he is able to see over the ridge in front.

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Measuring the Range.

The distance from gun to target is found by direct measurement from the map, or by measuring the distance from the observing post to the target and to the battery with the range finder, and combining the results with the field plotter. This instrument, the present form of which is due to Colonel Guthrie-Smith, R.F.A., has the great advantage that it is practically impossible to make a mistake in reading it. It consists of two arms graduated in yards, each pivoted on a semi-circular arc divided into degrees. The pivots can be set at any required distance by a slide also graduated in yards.

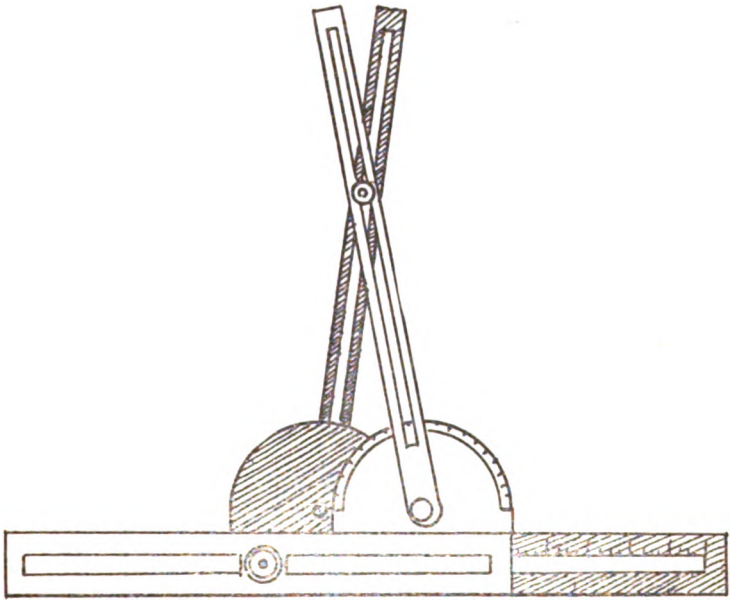

FIG. 72.

Say that the distance from observing point to battery is found to be 370 yards, and that from observing point to target 3400 yards, the included angle being 120°. Set the base scale at 370; set one arm at 120°, and slide the screw clamp which connects it to the other arm to 3400. Then the length of the other arm will give the range from battery to target, and the angle of the other arm the angle from the battery between observing point and target. For simplicity these graduations are marked on the reverse side; therefore, having set it, turn it over and read off the range and the angle. This ingenious arrangement is useful in avoiding mistakes.

The plotter is only graduated up to 4500 yards, but by working in double or treble yards it can be made available up to any range. Thus if the observing point range be 4800, base 520, and angle 135°, set the base scale at 260, the arm at 135°, and the screw clamp at 2400; and the range reads 2575 double yards, or 5150 yards.

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Finding the Line.

If the "forward covered position" is selected, the line is best obtained by standing on a wagon limber behind the gun, or upon the gun itself, and laying out one aiming post in front. If the "retired covered position" is selected, as will usually be the case, there are several methods of getting the line. The principal are:

Two aiming posts and aiming point.
Director.
Aiming point and director.
Two Directors.

Two Aiming Posts.

This is useful in certain cases, where the ground is cramped and unsuitable to the other methods, or when no director is available. Set up two aiming posts in line with the target; run a gun (a centre one if possible) into line with them; measure the angle between the line of fire of this gun and a distant aiming point; lay the other guns by the same aiming point.

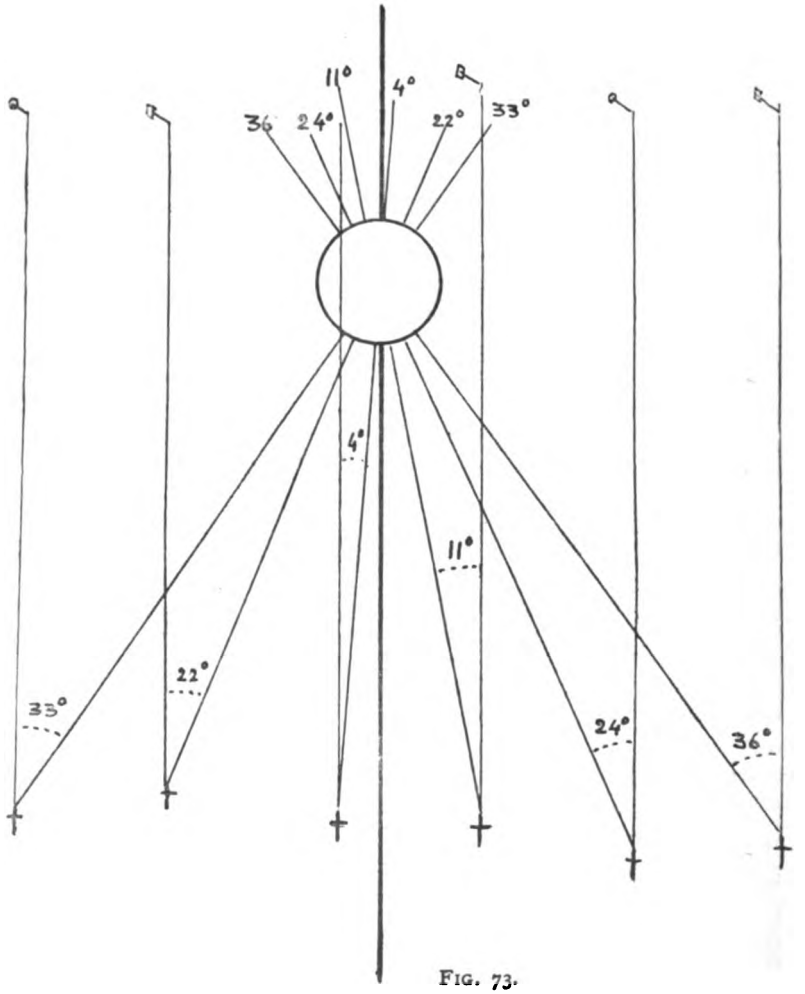

FIG. 73.

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Director.

This is the most generally useful method, and has the advantage of giving parallel lines of fire.

Use the director as laid down in Section Gun Drill. Set up the tripod and director on the crest in front of the battery; set the base-plate at 180°, clamp it, lay the director on the target, clamp it to the base-plate, slack off the screw clamping the base-plate, and turn base-plate and director round till the former is at zero; then the director will be pointing directly away from the target. Measure the angle right and left of the zero to each gun; write down the angles,

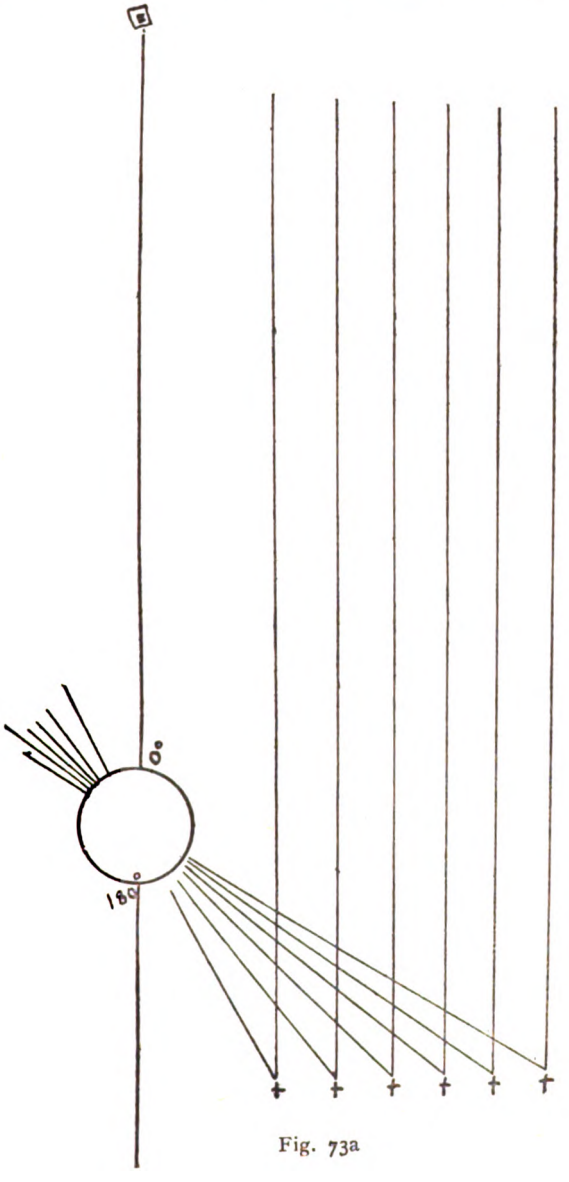

Fig. 73a

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send them to the battery, and let each gun lay on the director (or rather on a flag planted under it) with the same angle which it bears from the director. The effect of this proceeding will be to lay all the guns parallel to the line from the director to the target.

This presupposes that it is possible to set up the director in front of the centre of the battery. But if the battery be behind a wood, village, or similar cover, then the director must be set up outside one flank of the battery. If the director be pointed at the centre of the target, then all the guns, being layed parallel to the line of the director, will be off the target, as in Fig. 73a. To remedy this, it is necessary to point the director off the target by an amount equal to the lateral (estimated) distance of the director from the battery. If this be done accurately the effect will be to bring each gun on to its own portion of the target, as in Fig. 73b.

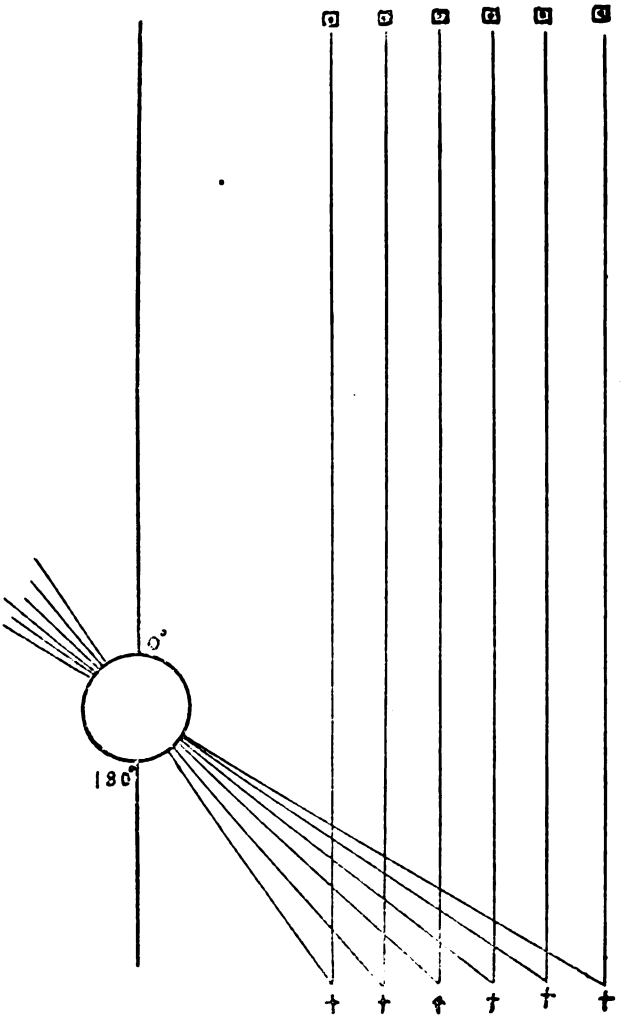

Fig. 73b

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Two Directors.

Suppose the battery posted as in the following sketch, so that the observing point is not visible from the battery.

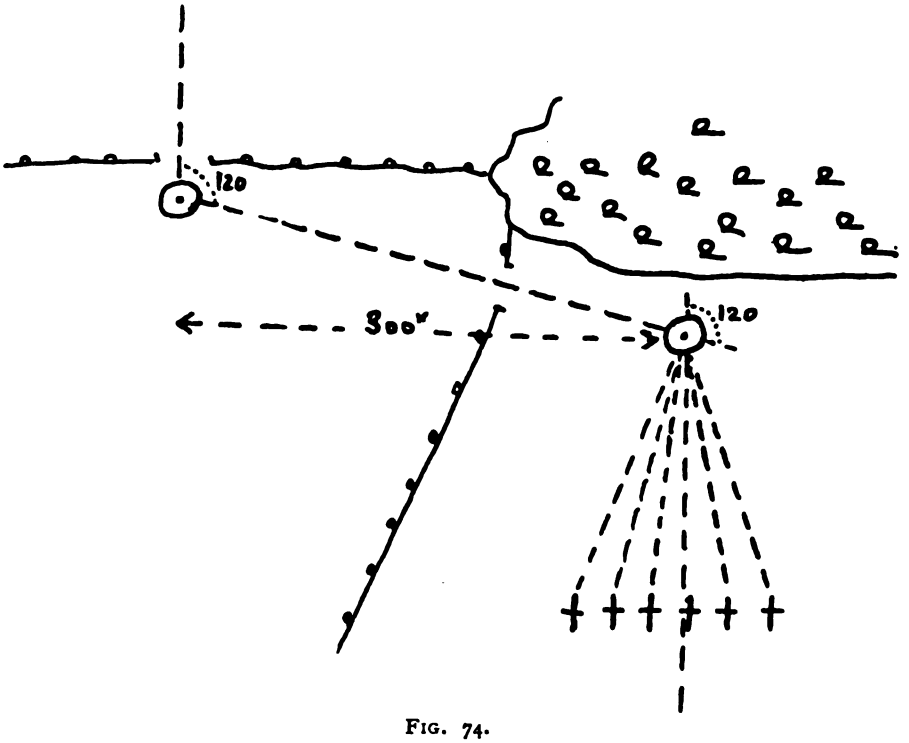

FIG. 74.

Set up a director at the observing point with zero towards the target and measure the angle from the target (or rather from a point 300 yards left of it) to the second director, in front of the battery. Say the angle is 120°. Set the second director at 120° and lay back on the first; then the two directors will be set up parallel, and the zero of the second director will point at the target. Then give each gun its angle from the second director. If only one is available, it may be shifted from one point to the other, each point being marked by a flag.

The Aiming Point.

This is in some ways the simplest method of getting the line. But unless chosen square to a flank it will give converging or diverging lines of fire, requiring a special correction for parallelism before opening fire.

The Choice of an Aiming-point.

If all the guns are layed at the same angle on an aiming point infinitely distant, then all the lines of fire will be parallel. If they are layed on an aiming point close at hand—say 100 yards to the

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right front—it is evident that the six lines of fire will converge at little more than 100 yards from the battery. In order to obtain actual convergence of all six lines of fire at the target, it is necessary that the aiming point should be on the circumference of a circle having its centre in the line of fire and passing through the battery and the target, as at A, Fig. 75. This follows from the geometrical proposition that angles in the same segment of a circle are equal.

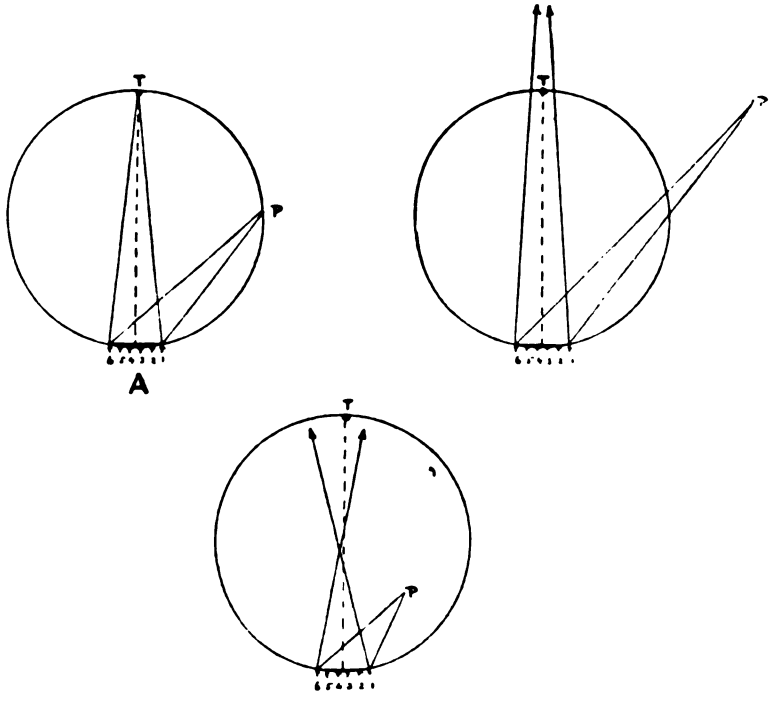

FIG. 75.

Since it tends to confuse observation of fire if the shell from the right gun are pitching on the left of the target, and vice versâ, the aiming point should when possible be chosen outside the above-mentioned circle. And the battery commander must remember that if his aiming-point be distant in comparison to the target, or if it be square to a flank, the effect will be to distribute fire from the first round. This must be taken into account in ordering deflection.

It will rarely be desirable to choose an aiming point in rear of the battery, except at a very wide target, since such an aiming point gives diverging lines of fire.

Use of the Aiming Point.

If the Battery Commander, from his observing post, observes a conspicuous aiming point, say 70° to the right of the target, then it does not follow that this angle, if given to the battery, will bring the guns on to the target.

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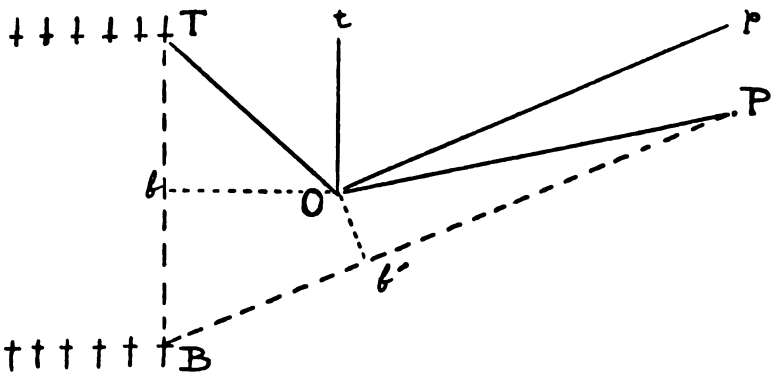

FIG. 76.

What we require, to lay the guns for line, is not the angle TOP but the angle TBP. This may be obtained in two ways :—

(a) Suppose the observing post 300 yards right of the battery, and 150 yards in front of it. Lay the director not on the target but on a point *t* 300 yards right of the target and then swing it round till it is directed on a point *p* 150 yards in front of the aiming point, and read the angle. This angle, *t* O *p*, is the same as TBP, the angle required.

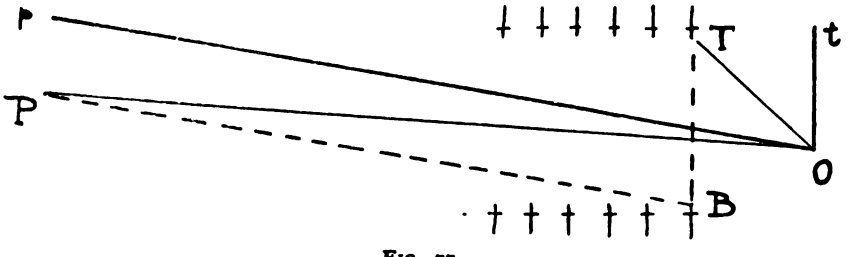

FIG. 77.

If the aiming point be on the opposite flank, as in the second figure, the procedure is the same.

(b) Instead of estimating the distance T*t*, P*p*, which is liable to error, we may calculate the angles TO*t*, PO*p*.

If in Figure 76 we first estimate the distance Ob at 300 yards, and Ob' at 120 yards, then if the target be 4000 yards distant TO*t* will be $\frac{300 \times 36}{40}$ minutes or 4½ degrees. If the aiming point be 6000 yards distant PO*p* will be $\frac{120 \times 36}{60}$ minutes or 1 degree 12 minutes. In this instance both these angles have to be deducted from the angle TOP to get the required battery angle TBP. Thus if TOP be 70°, TBP will be 64° 18'.

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Similarly in Figure 77 TO*t* will have to be added to 70° and PO*p* subtracted from it, to get the battery angle. There is a risk of confusion here which is best avoided by sketching the lines in one's notebook.

The calculation of TO*t*, PO*p*, is facilitated by using the following short table.

DISPLACEMENT TABLE.

Distance of Director from Line of Fire.

100″ at 2000 = 3°
" " 3000 = 2°
" " 4000 = 1½°
" " 5000 = 1¼°
" " 6000 = 1°

Finding the line with the plotter.

We have already described the use of the plotter as a range-finder. An even more important application of it is its use for finding the line.

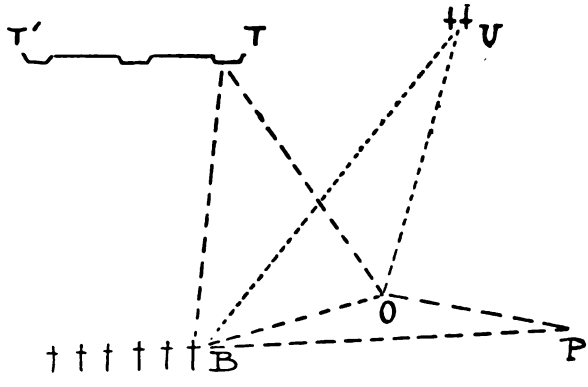

FIG. 78.

The battery being posted as in Fig. 78, the plotter may be used in any of the following different ways:

(a) Solve the triangle TOB; this gives the angle TBO, which fixes the line from the battery to the target with reference to the observing point.

(b) Solve triangles TOB, POB; then the sum of the angles TBO, PBO, is the angle TBP, which fixes the line from the battery to the target with reference to the aiming point.

(c) To save the trouble of taking the range to P, the angle PBO may be observed from the battery and sent up by telephone.

(d) To find the angular width of the target T'T from the battery, solve the triangles TOB, T'OB: the difference between the angles TBO, T'BO is the angular width required.

(e) To switch on a fresh target U, solve the triangles TOB, UOB; the difference between the angles TBO, UBO, is the true switching angle.

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Practical Methods.

It might appear from the foregoing that the determination of the line of fire from a covered position is a complicated and difficult matter. But when the battery staff thoroughly understand the procedure, this is by no means the case.

Of the various possible methods, the writer prefers the following :—

(*a*) Use the director and sights as laid down in F.A.T., 1906, section 41.

(*b*) When the conditions are easy, lay the director off the target and off the aiming-point as in Fig. 76 or 77. Send down the angle thus obtained to the Battery Leader, and leave him to give the corrections for parallelism, etc., to the sections.

(*c*) When observation is difficult, and it is necessary to get the line accurate at the first round, take the ranges from observing point to the target and to the point where the nearest flank gun of the battery will be posted. This point is marked by the trumpeter or second signaller, or with a flag. Solve the triangle TOB, Fig. 78, with the plotter. When the battery comes up send down the angle TBO.

The Battery Leader directs the flank gun to lay (with its goniometric sight) on the observing point at the angle TBO; this gun is then pointing at the target.

Having got the line for one gun, the Battery Leader can choose his own method of getting the remaining guns on the target. If a suitable distant aiming point is available, he can turn the sight of the flank gun upon it and give the other guns the angle thus obtained, corrected if necessary for displacement. Or he can set up his director in front (or in rear) of the centre of the battery, set it parallel to the goniometric sight of the flank gun (as in the two-director method) and then give each gun its angle.

It is possible to lay two guns parallel to each other with accuracy by laying on each other's goniometric sights. The Battery Leader, having been given the line for one gun, may thus give the other guns their lines from it. But unless the battery is on hollow ground, so that the "standard gun" has a good view of the others, this method is difficult to apply.

(*d*) When the Battery Leader is well ahead of the battery, as he should be, and when the ground is suitable, the two-director method is the quickest and best. The second director is set up and aligned before the battery arrives, and each gun as it comes into action gets its angle at once.

Parallelism of Lines of Fire.

So far we have obtained the correct line, say, from the right gun of the battery to the right-hand end of the target. But unless the aiming point is square to the flank, the lines of fire of the remaining guns will not be parallel to that of the flank gun; thus, if the aiming point be to the front they will tend to converge on the right-hand end of the target, requiring a correction to make the fire cover the

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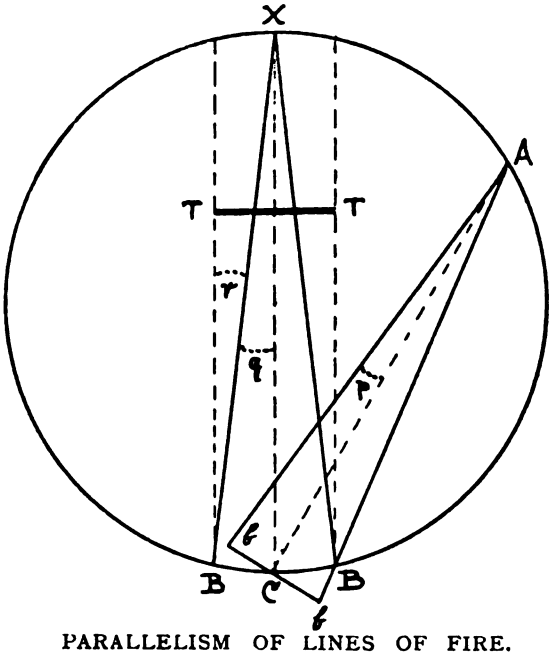
left and centre. Further, if the target be wider than the battery, a second correction will have to be given to distribute the fire over the whole target. In the English Artillery the problem is solved as follows:—

Calculate the correction required by each section so as to bring the three lines of fire of the sections parallel. The battery will then cover a front of the target equal to its own. Then combine with this a second correction such as will give the lines of fire sufficient divergence to cover the whole target, so that each section has one-third of the target to fire on. Finally, if necessary, order each section to sweep so as to cover the front assigned to it.

In the French artillery the first correction given is for convergence, not for parallelism, and it is given to three out of the four guns, not two out of the three sections as with us. Our method has the advantage of being equally applicable to the case when the director is employed—when no correction for parallelism of lines of fire is required—and to the case when an aiming point is employed. The French method is suitable to the second of these cases only. If we worked on the French system we should either have to use two different systems of giving corrections, one for the case where the lines of fire are parallel, the other for the case where they are not; or else, in the former case, we should have to give an entirely unnecessary correction for convergence to parallel lines of fire, preparatory to opening them out again, like the sticks of a fan, for distribution.

We will now consider the theory of the method of finding the two corrections, namely for parallelism and distribution.



PARALLELISM OF LINES OF FIRE.
FIG. 79.

A battery BB is engaging a target TT, whose front is equal to that of the battery, from behind cover. All guns are layed on an aiming point A. It is required to assign to the guns such angles of direction as will distribute the fire over the target.

In this instance this is equivalent to getting the lines of fire parallel.

If the guns are layed on the aiming point at the same angle, so that the centre section is on the centre of the target, the lines of fire will all meet at a point X beyond the

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target on the circumference of the circle BAB. Then the angles BXB and BAB, in the same segment of a circle, are equal, and the isosceles triangles BXB, *b*A*b* are similar. The supplementary angle TBX, required to bring the left gun on to the left of the target, is equal to BXC, that is to *b*AC, that is to the angle subtended at A by the distance *b*C, or the "projection" at right angles to CA of half the front of the battery. This correction would be added in giving the angle to the left gun, and subtracted for the right gun.

Similarly, if the angle given to the battery be such as to bring the right gun on to the right-hand extremity of the target, then the correction for the left gun, to bring the lines of fire parallel, will be equal to the angle subtended at A by the projection at right angles to CA of the whole front of the battery.

For instance, let the front of the Battery be 100 yards, and the distance of the aiming point 4000 yards. The distance from the right gun to the straight line from the left gun to the aiming point is found by pacing to be 80 yards.

Then 80 yards at 4000 $= \frac{80 \times 36}{40}$ minutes $= 72$ minutes $= 1\frac{1}{5}$ degrees nearly. That is, in practice, if the angle for the right gun be "line of fire 30 degrees left," then the order for the centre section will be "30½ left," and for the left section "31 left."

In a French 4 gun Battery the correction (known as the "échelonnement") is calculated for each gun before opening fire. With six guns this involves too much arithmetic, and it is considered sufficient in our service to give the correction for each section.

Displacement Table.

From the foregoing explanation it may be deduced that the displacement correction for parallelism is independent of the range, dependent on the angle at the Battery between target and aiming point, and inversely proportional to the distance of the aiming point. This gives us the means of constructing a table of displacement, which is conveniently made out on a section basis. That is, the table supposes that the guns are at regular intervals of 20 yards, and that the ranging section has been given a line which brings it on to its own end of the target; the table then gives the correction required to bring the centre section lines of fire parallel to those of the ranging section. Double this correction will bring the lines of fire of the third section parallel to those of the first. Or if ranging with the centre section, which is in many respects preferable, a single correction to each flank section will give the desired result.

If the aiming point be in front of the Battery, that is between 0° and 90°, the lines of fire will converge, and the corrections must be given outwards, away from the directing flank.

If the aiming point be in rear of the Battery, between 90° and 180°, the lines of fire will diverge, and the corrections must be given inwards, towards the directing flank.

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SECTION DISPLACEMENT TABLE FOR PARALLEL LINES OF FIRE.

Angle between target and aiming point. Degrees.		Correction in minutes for each section, for an aiming point distant yards:					
		2000	3000	4000	5000	6000	7000
Correct Outwards.	Correct Inwards.						
0	180	72	48	36	29	24	21
10	170	70	47	35	28	23	20
20	160	68	45	34	27	22	19
30	150	62	41	31	25	20	18
40	140	55	37	27	22	18	16
50	130	46	30	23	18	15	13
60	120	36	24	18	14	12	10
70	110	25	16	12	10	8	7
80	100	13	8	6	5	4	3
90	90	0	0	0	0	0	0

For instance, if the Right Section be the ranging section, and the aiming point be 60 degrees from the right hand end of the target and distant 3000 yards, the order to the Battery would be:

"Aiming point Church steeple."
"Right Section line of fire 60° left."
"Centre ,, ,, 60½° left."
"Left ,, ,, 60⅓° left."

If the aiming point be 170° from the target and distant 3500 yards, the order would be:

"Aiming point, Church steeple."
"Right Section line of fire 170° left."
"Centre ,, ,, 169½° left."
"Left ,, ,, 168⅓° left."

Between 80° and 100° the correction is so small as to be negligible, and endeavours should always be made to obtain an aiming point within these limits.

It must be remembered that the accuracy of these corrections is dependent upon the guns being at correct intervals and in dressing. The latter is especially important when the B.C. is obliged to use an A.P. within 2000 yards of the battery.

Wide Targets.

Where the target is wider than the front of the battery, it is desirable, before opening fire, to give each section a line such that the fire is distributed over the whole front of the target. Each section is afterwards ordered to sweep so as to completely cover the portion assigned to it. It is impossible to combine the correction for parallelism and distribution into one table, since the former depends exclusively upon the distance and angle of the aiming point, the latter upon the range and front of the target. The two corrections

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must be reckoned separately and added together or subtracted before the angle for each section is ordered.

Let TT be the target and BB the Battery. Suppose the right section the ranging section, and the line of fire laid out so as to bring the right section on to the centre of the right hand portion of the target. It is required to find the correction to be given to the centre and left sections.

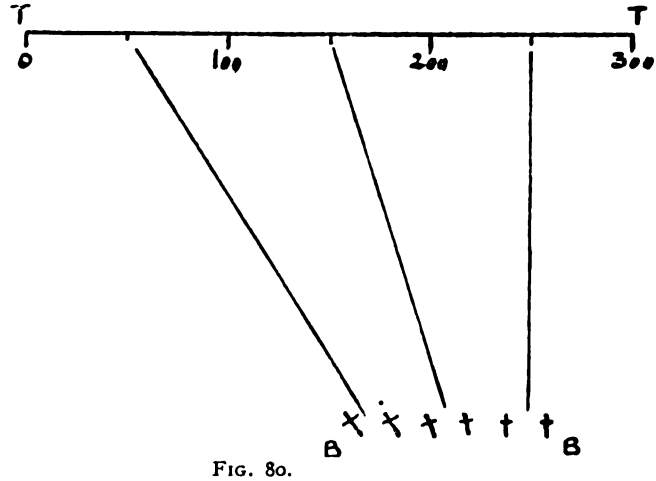

FIG. 80.

The right section line will be directed on point 250, and the centre section line (if parallel to the right) on point 210. To bring it on to point 150, the centre section therefore requires a correction for 60 yards at 3000 or $\frac{60 \times 36}{30} = 72$ minutes, the left section, being directed on point 170, requires, to bring it on to point 50, a correction of $\frac{120 \times 36}{30} = 144$ minutes, or twice that for the centre section.

This works out mathematically as follows:—

It is required to divide the target into 3 equal portions, and to bring the line of fire of each section on to the centre of the corresponding portion.

Then, if f be the front of the target in yards,

r the range in hundreds of yards,

the interval between the lines of fire of two sections will be $\frac{f}{3}$ or in minutes $\frac{f}{3} \times \frac{36}{r}$.

But since the sections are 40 yards apart from centre to centre, then, if the lines of fire are parallel, 40 yards of this, or in minutes $40 \times \frac{36}{r}$ is already given.

Therefore, if c be the total correction in minutes for one section,

$$c = (\frac{f}{3} - 40)\frac{36}{r}$$

$$= (f - 120)\frac{12}{r}$$

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From this we work out the following table:

TABLE OF DISTRIBUTION CORRECTIONS FOR EACH SECTION.

Front of Target. Yards.	Range 1000 Yards.	Range 2000 Yards.	Range 3000 Yards.	Range 4000 Yards.	Range 5000 Yards.	Range 6000 Yards.
150	36′	18′	12′	9′	7′	6′
200	1° 36′	48′	32′	24′	19′	16′
300	3° 36′	1° 48′	1° 12′	54′	43′	36′
400	5° 36′	2° 48′	1° 52′	1° 24′	1° 7′	56′
500	7° 36′	3° 48′	2° 32′	1° 54′	1° 31′	1° 16′
600	9° 36′	4° 48′	3° 12′	2° 24′	1° 55′	1° 36′

This table is suitable for an officer to carry in his notebook, but it is not generally useful in action. It is far easier to measure the front of the target in degrees, with the deflection scale at arm's length, than to estimate its width in yards. If in the above formula we substitute degrees for yards of front, we get:

$$\text{Correction in degrees for one section} = \frac{D}{3} - \frac{24}{r}$$

Where D is the angular width of the whole target and r the number of hundreds of yards in the range. The following table, based on this converted formula, is a practically useful one, and should be marked on the back of the officer's deflection scale.

DISTRIBUTION CORRECTION FOR EACH SECTION.

Front of Battery Target. Degrees.	Range 2000 Yards.	Range 3000 Yards.	Range 4000 Yards.	Range 5000 Yards.	Range 6000 Yards.
3	— 12′	12′	24′	31′	36′
4	8′	32′	44′	51′	56′
5	28′	52′	1° 4′	1° 11′	1° 16′
6	48′	1° 12′	1° 24′	1° 31′	1° 36′
7	1° 8′	1° 32′	1° 44′	1° 51′	1° 56′
8	1° 28′	1° 58′	2° 4′	2° 11′	2° 16′
9	1° 48′	2° 18′	2° 24′	2° 31′	2° 36′
10	2° 8′	2° 38′	2° 44′	2° 51′	2° 56′
15	3° 48′	4° 12′	4° 24′	4° 31′	4° 36′
20	5° 28′	5° 52′	6° 4′	6° 11′	6° 16′

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EXAMPLE.—Target, a trench 6° wide at 4000 yards. Right section ranging section. Then distribution correction for centre section is 1° 24′, that for left section 2° 48′.

Use of the Plotter for Distribution.

With a wide target, especially if it is not at right angles to the line of fire, the best method is to work out the line to each end of it with the plotter. The difference between the two angles thus obtained gives the angular front of the target as measured from the battery; and half the sum of these angles gives the line to the centre of the target.

Alternative to Distribution.

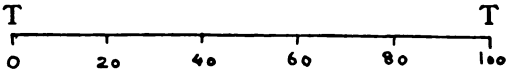
Instead of distributing fire over the whole front of the target from the outset, we may attack the different portions of the target in succession. If the target be a trench 300 yards long at 2500 yards, we may first attack the right-hand hundred yards of trench, then give "all guns 2° more left," which will bring the centre hundred yards under fire, and finally repeat the same order to attack the left-hand portion of the trench. But on tactical grounds this procedure is far inferior to attacking the whole target simultaneously, giving each section a different direction and ordering each section to sweep the portion of target assigned to it. The correct order in the present instance, supposing the ranging carried out with the centre section on the centre of the target, and the direction found to be 20° left of the aiming point as before, would be

"Right section line of fire 17° left"
"Centre ,, ,, 20° left"
"Left ,, ,, 23° left"
"Sweep ¾ degrees right and left."

Whenever possible, the aiming point, if one is used, should be taken square to a flank, or nearly so. This does away with the correction for parallelism and simplifies the calculation of the deflection required to cover the target.

Theory of Sweeping.

The unit of fire, as regards the front to be covered, is the section. It is important to know what front a section will cover at different angles.



Let TT be a target 100 yards long. Then if the fire of the section be directed on the centre of this with lines of fire parallel, the shell will fall at points 40 and 60. Take the average effective width of the shrapnel cone at 15 yards. Then, to be absolutely accurate, the line of fire of the left gun should sweep from point 7½ to point 42½, that of the right gun from point 57½ to point 92½. At 3000 yards, then, the left gun should first give deflection sufficient to shift the point of impact from point 40 to point 25, namely $\frac{15 \times 36}{30} = 18$ minutes, and should thence sweep $\frac{(25 - 7\frac{1}{2})\ 36}{30} = 21$ minutes right and left.

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This calculation is the basis of the following table.

SECTION COMMANDER'S SWEEPING TABLE.

Front of Target 100 yards.

Range. Yards.	Outward deflection for each gun. Minutes.	Sweep Right and Left. Minutes.
1000	54	60
2000	27	30
3000	18	20
4000	13	15
5000	11	12
6000	9	10

Table Simplified.—Front of Target 100 yards.

Range. Yards.	Outward Deflection and Sweep.
1000	60′
2000	30′
3000	20′
4000	15′
5000	12′
6000	10′

This table may be carried in an officer's note-book. But for ordinary practical purposes a further simplification may be effected. If we multiply the front of the target in degrees by 10, this will give the outward deflection and sweep required in minutes.* Thus for a target of 3 degrees front, at any range, the order to a section would be:

"No. 1, 30 minutes more right deflection."
"No. 2, 30 minutes more left deflection."
"Sweep ½ degree right and left." †

* I am indebted for this rule to Major C. Battiscombe, R.F.A.

† The word *sweep* is not here used in the limited sense in which it is employed in F.A.T., 1906. The latter book restricts it to a special case, in which the number of rounds per gun is limited to three, and the rate of fire to rapid fire. In a wider sense sweeping means distributing fire laterally over a given front. There is no reason why sweeping should not be employed at deliberate fire.

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Theory of Switching.

Let it be required to turn the fire of the Battery on to a new target, which the Battery Commander from the observing position observes to be at a certain angle with respect to the old one.

Then the angle which the new target subtends from the battery will not necessarily be the same as that observed from the observing point. For small angles up to 5° this correction may be neglected; but for large angles, or where accuracy of line is required, as in the case of a howitzer battery, the switching angle must be calculated or measured, as afterwards explained, with the field plotter.

The procedure in switching is based on the following theoretical demonstration, for which I am indebted to Major G. H. Geddes, R.F.A.

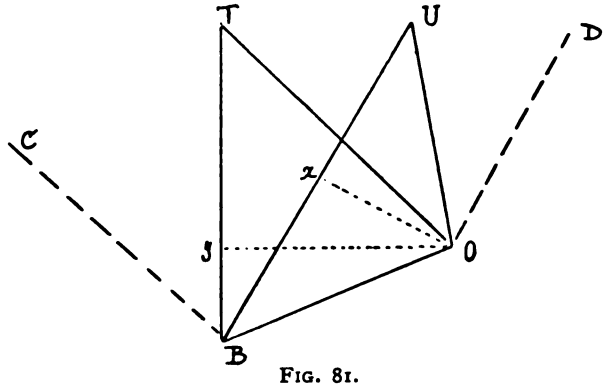

FIG. 81.

Let B be the Battery, O the observing point. Let the distance BO be called the base.

Let T be the old target, U the new target, and let U be on the same flank as the observing point.

Draw BC parallel to OT, and OD parallel to BU.

Then angle TOD = angle UBC, since the lines containing these angles are parallel.

But angle TOD = TOU + UOD.

And UBC = TBU + TBC.

Therefore TBU + TBC = TOU + UOD.

Therefore TBU = TOU + UOD − TBC.

But UOD = angle U, and TBC = angle T, between the same parallels:

Therefore TBU = TOU + U − T.

That is to say, the angle of switch to be given to the battery is equal to the angle measured at the observing point, plus the angle subtended by the base at the new target, minus the angle subtended by the base at the old target.

For instance, let OT be 5000 yards, OU 3000 yards, and let the base be 350 yards. Estimate Ox 400 yards and Oy 500 yards.

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Then, since one minute is equal to an inch at a hundred yards, we "reduce the error to inches and divide by the number of hundreds of yards in the range."

$$\text{Then angle U} = \frac{400 \times 36}{30} = 480 \text{ minutes} = 8 \text{ degrees}$$

$$\text{angle T} = \frac{500 \times 36}{50} = 360 \text{ minutes} = 6 \text{ degrees.}$$

Therefore if from the observing point we measure the angle between old and new target 20 degrees, the switch angle for the battery will be 20 + 8 — 6 or 22 degrees.

When the new target is on the *opposite* flank to the observing point we find by a similar construction TBU = TOU + T — U.

When the new target is on the distant flank we must therefore add to the observed angle the angle subtended by the base at the old target, and subtract that at the new.

Once the theoretical principle of the determination of the switching angle is clearly understood, its practical application becomes a simple matter.

A change of target does not usually allow time for the calculation of the angles T and U.

But there is plenty of time to use the equivalent method of laying the director off the target by an amount equal to the perpendicular distance from the line of fire.

Suppose the battery in action, the Battery Commander 400 yards to the right of the line of fire. Then in measuring his aiming-point angle he has already layed the director, set at zero, on a point T 400 yards right of the target. A new target appears further to the right: the Battery Commander judges that he will be about 200 yards to the right of the new line of fire: he points his director 200 yards to the right of the new target and reads off the angle T'OU', which is equal to TBU, the true switching angle.

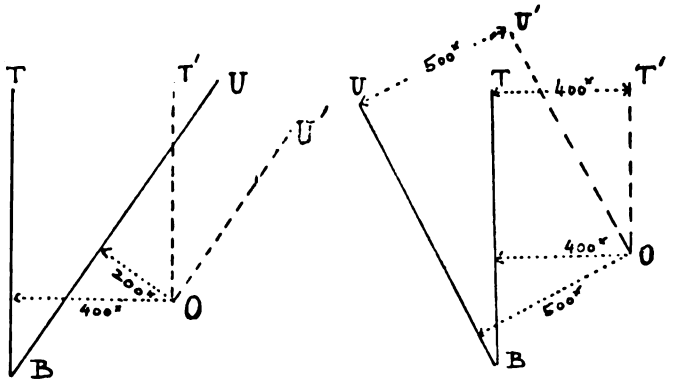

FIG. 82.

In this instance laying the director on T' is equal to giving the correction (— angle T), and laying it on U' is equivalent to giving the correction (+ angle U).

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Similarly if a new target U appears to the left or opposite flank, the Battery Commander judges that he will be 500 yards right of new line of fire and lays on U' accordingly; in this case the original correction, given by pointing the director 400 yards right, goes to increase the new angle, and the process is equivalent to giving angle TOU + angle T — angle U, which gives the true switching angle as before.

The foregoing method requires no calculation, and is suitable for horse and field guns under ordinary tactical conditions. But in the case of 4.7 guns or howitzers it is desirable to use a more accurate method. We may either measure Ox, Oy, (Fig. 81) and calculate angles T and U; or we may use the field plotter.

If, in Fig. 81, we set the base OB, the range OT, and the angle TOB on the plotter, then we get, on turning the plotter over, the angle TBO. And if we repeat the process for the new target we get the angle UBO. The difference between these two angles is the true switching angle.

One practical advantage of using the plotter to find the angle of switch is that it is easier to estimate or measure the base OB, to a fixed point, than the distances Ox, Oy, to imaginary and possibly inaccessible points.

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DISTRIBUTION OF BATTERY STAFF DURING ADVANCE INTO ACTION. OPEN COUNTRY.

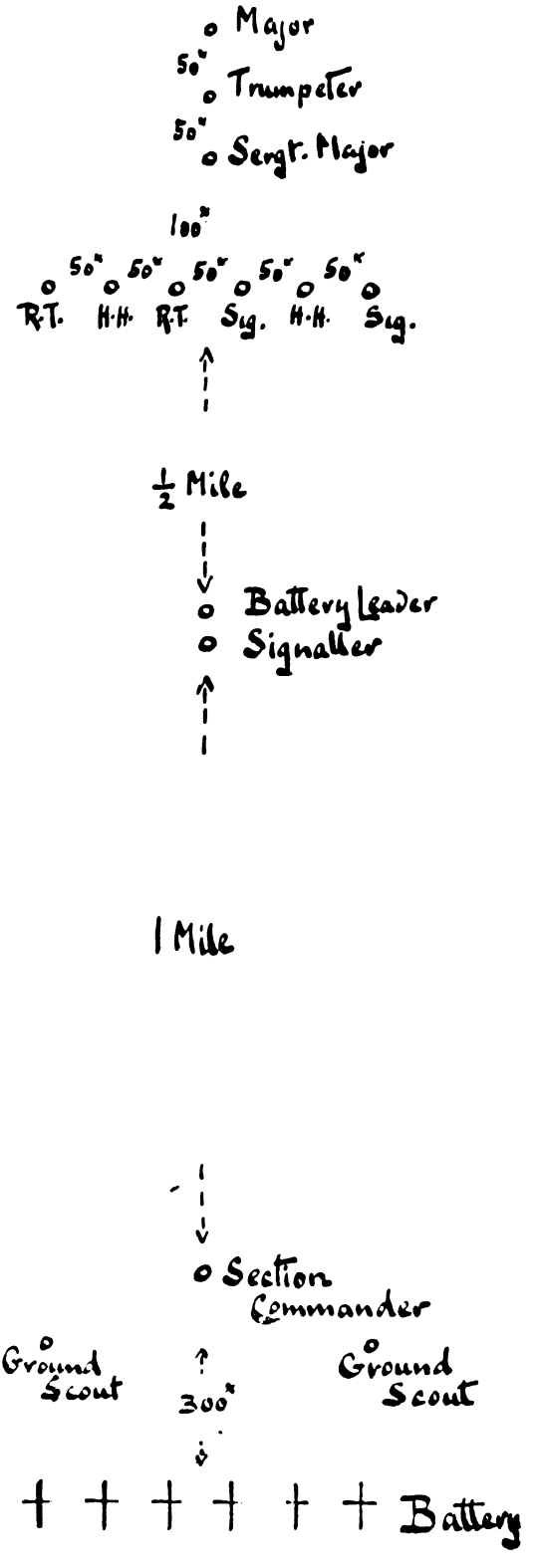

FIG. 83.

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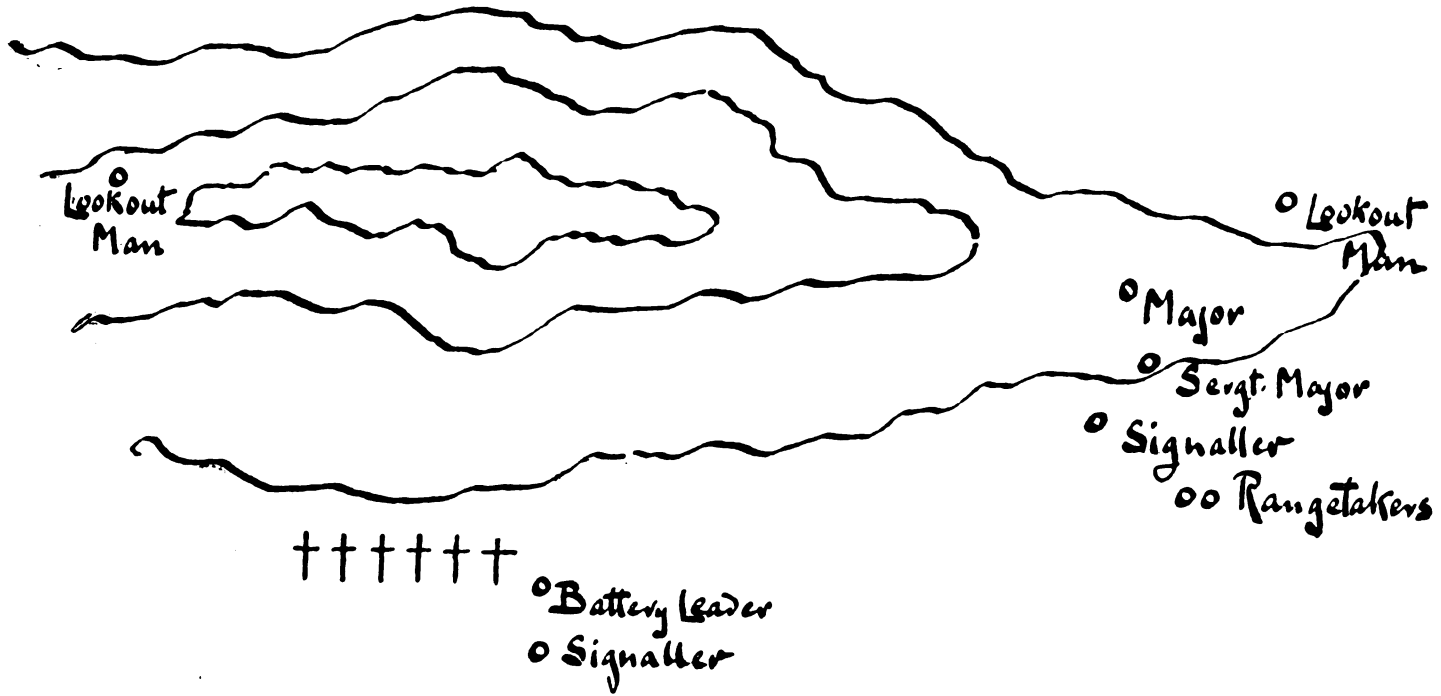
DISTRIBUTION OF BATTERY IN ACTION.

FIG. 84.



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CHAPTER XXIII.—CONTINUED.

Practical Application of the Principles of Indirect Fire.

Our new Q.F. gun is equipped with a goniometric sight for all-round laying, and with a clinometer capable of being set to the angle of sight for laying for elevation. Two telephones, with 880 yards of light wire per battery, are also carried. These improvements render the equipment specially well adapted for firing from behind cover. Whether the covered or the direct position is used is a matter of tactics, not of gunnery; but F.A.T. 1906 lays down that fire from behind cover will in future be the normal method.

It is therefore of the greatest importance that not only the principles governing the use of indirect fire, but every detail of their practical application, should be familiar to all concerned.

In the following paragraphs it will be assumed that the distribution of the Battery and Staff is as shown in Figs. 83 and 84.

The telescope, director, and stand are carried by the senior rangetaker; the field plotter by the second rangetaker. Two mounted signallers accompany the Battery Commander, each carrying, besides his flags, a telephone and two reels of wire. They communicate with the battery either by telephone or by the semaphore code given in F.A. Training.

The battery director and stand are carried by a mounted signaller who accompanies the battery leader.

On coming into action the two ground scouts become the look-out men, and take post on the crest right and left of the Battery.

The horses are held as follows—

Sergt.-Major's by 1st trumpeter.
B.C.'s signallers' by signallers' horseholder.
Rangetakers' by rangetakers' horseholder.
Remainder by limber drivers.

It must be clearly understood that when the battery is in action under cover and the Major observing from a point say 800 yards to the right front, the Major always retains command of the battery, and never subsides into a mere observing officer. Under normal circumstances, as when using the telephone, he gives all executive orders just as if he were standing beside the battery.

But when signallers are the only available means of communication, then, in order to expedite the transmission of his orders, the Major is allowed to use the system of double signallers described in F.A.T., 1906. In this case the senior subaltern with the battery gives the actual word of command corresponding to the Major's observation, and reports his order to the Major. Thus instead of

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the Major having to signal down "both guns 4400," he merely signals "short," when the subaltern orders the normal increase of elevation, and the second pair of signallers report the order given to the Battery to the Major. It is also permissible to use the double-chain signallers to repeat the Major's executive orders back to him, in order to ensure that they have been correctly received.

The fact of the Major observing does not preclude the use of an additional observing party to the right or left front, whose duty, if employed, is to keep the Major informed of the effect of his fire. If the tactical conditions permit of the establishment of such a party in a position where they have a good view of the target they may be of the greatest use.

F.A.T. 1906 also allows an alternative method, in which the Major remains under cover with his battery while a junior officer observes the effect of the fire. But the cases which would justify the Major in abandoning direct personal touch with the battle, and delegating his most important duty—the observation of the course of the combat, and corresponding control of his fire—to a subordinate, must be considered exceptional.

The foregoing details relate rather to tactics than to gunnery, but it is necessary to enter into them in order that the practical application of gunnery principles may be clearly understood.

The Angle of Sight.

The Major arrives at the position say 10 minutes in advance of the battery. Having selected his position and that of the battery (the latter with due regard to clearing the crest and to switching on to other possible targets), his first duty is to determine the angle of sight. For this he lays the telescope or director on the target and reads off on the scale of the level on the left of the telescope the angle of elevation or depression of the target above or below his own position. He has now to find the angle of the target above or below the battery.

For small angles it may be laid down that the angle subtended by the target varies inversely as the range. Thus, the Major finds that the angle of sight (or "target altitude") from his own position is minus 2° 20′; his range to the target is 3000 yards, and the battery is to be 500 yards further to the rear, or 3500 yards from the target; then the target altitude from the battery is $\frac{3000}{3500} \times 140' = 6/7 \times 140' = 2°$. Next he must consider the difference of level between himself and the battery. If the battery be estimated to be 30 feet below the Major, then it will require additional elevation for 30 feet at 3500 yards. Reduce to inches and divide by the number of hundreds of yards in the range, and this gives $\frac{30 \times 12}{35} = 6/7 \times 12 = 10'$ nearly; therefore angle of sight for battery will be minus 2° 10′.

Where the difference of level between Major and battery is considerable, the angle should be measured with the clinometer on the telescope, and the range to the battery taken by the rangetakers

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(working in quarter yards with quartered cord). Thus, range to battery 450 yards, angle 3° depression; one minute equals an inch at 100 yards or 4½ inches at 450 yards; height of Major above battery is $\frac{4\frac{1}{2} \times 3 \times 60}{12} = 4\frac{1}{2} \times 3 \times 5 = 22\frac{1}{2} \times 3 = 67$ feet.

When the enemy's position can be located on a contoured map, the angle of sight from the battery to the target can be measured directly. Thus, the enemy is on the 350 contour 4000 yards from the battery; the battery is in a hollow ⅓ of the way down from the 300 to the 250 contour, that is at 285 feet, or 63′ below the target.

$$\frac{65 \times 12}{40} = \frac{65 \times 3}{10} = 19.5 \text{ minutes.}$$

It may be supposed that undue importance has been attached to the accurate determination of the angle of sight. But it will be found that the extra time spent in calculating the angle is more than saved in ranging and fuzing. Thus, an error of —½ degree in the angle of sight at 3500 yards will not only throw out the range 200 yards, but, when this has been corrected by increasing the elevation, it will still throw out the fuze 200 yards, with the result that if the fuze ladder ordered is such as should burst the last fuze 200 yards short, all four fuzes will burst on graze, thus wasting the whole ladder.

Having found and recorded the angle of sight, the next proceeding is to find the line of fire.

The method least liable to error is to set up the director tripod, with a flag under it, as nearly as possible between the centre of the battery and the centre of the target, and give each gun its angle as already described. The angles may be communicated to the battery by telephone, by written message, or by calling up the Nos. 2. Or if a good aiming-point square to a flank is obtainable, the line may be given to a centre gun only; the gonio. sight of this gun is then directed on the aiming-point and the angle so obtained given to the whole battery.

In the majority of cases on service it will be found that the cover from view behind which the battery has to be brought into action is not a bare crest but a wood, a village, or a rise of ground with hedges and fences. In such a case it will be necessary to lay out the line of fire from a flank. The director may be used as before, provided that it is layed off the target by an amount equal to its lateral distance from the battery. This has the great advantage of giving parallel lines of fire, thus simplifying the distribution of fire.

Failing the director, a distant aiming point may be used. This should be chosen as nearly as possible square to the flank, so as to get parallel lines of fire. The angle to the aiming point must be corrected for double displacement, and must be such as to bring the flank ranging gun on to the corresponding flank of the target.

If preferred, the centre section may be used for ranging, and directed on the centre of the target; this simplifies the giving of deflection for distribution.

If an aiming point is used which is such as to give converging or diverging lines of fire, then the battery leader will order the necessary displacement correction for each section so as to bring the lines of fire parallel.

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If the front of the target exceeds that of the battery, then the Battery Commander will either order "front of target — degrees," in which case the deflection necessary for distribution is given by the battery leader, or he will himself order the distribution correction for each section.

In order to be able to direct the fire of the battery with confidence the B.C. must rely upon his battery leader to have the lines of fire parallel, whichever method of laying out the line of fire has been adopted. This gives a starting-point from which the fire can be concentrated or distributed as required.

These preliminary preparations are facilitated by marking the position which the battery is to occupy, say by sending the trumpeter with his led horse to mark for one flank gun, and the rangetaker's horseholder for the other flank gun. This gives a fixed point to which distances may be measured, and ensures the battery coming into action exactly at the place intended.

The battery, having come into action, is ranged by the Major in the usual way. Where the ground is undulating it is better not to begin with two shots at different elevations, as if one is lost there will be nothing to show which is the missing one. Correction for line is given on the first pair of rounds; the Major holding his deflection scale at arm's length, observes them pitch say 2¼ degrees to the left, and immediately orders "all guns 2½ degrees more right." If observing from the right, short rounds will appear more to the left than they really are, and plus rounds will appear more to the right.

The third pair of rounds, if near the target, should enable the final correction for line to be given. It then only remains to adjust each individual gun so as to get it on the corresponding enemy's gun, or portion of the target assigned to it. This is best done as follows: After the fuze ladder the Major orders "Corrector—one round battery fire 10 seconds." As these six rounds are fired he calls out the error of each, which is taken down by the Sergt.-Major or signaller, and the six corrections are sent down to the battery together. If one gun is badly out it may require a second correction, for which purpose it should be fired again by itself after the first correction has been given.

This minute correction of line is unnecessary at a trench or infantry target, but is essential when firing at guns, especially shielded guns, at which shells bursting in the intervals are valueless.

Fresh Target.

In switching on to a fresh target the Major must remember that the angle between the old target and the new target is not the same from the battery as from the observing station. For small angles, up to 5 degrees, no correction on this account is necessary. But if the angle be a wide one, as 25 degrees, then either the line to the new target must be laid out independently of the old target, or else the angle must be calculated by one of the methods already given. The field plotter gives most reliable results.

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Normal Procedure in Coming into Action.

Under normal conditions the procedure from start to finish will be as follows:—

1. Battery Commander receives his orders, reads them to officers, battery staff, and Nos. 1, and informs them where he intends to go.

2. He advances with Staff as in Fig. 83.

3. He arrives at his position, reconnoitres the enemy, selects his observing point, the position for the battery, general direction of position for limbers, and aiming point for battery.

4. He proceeds to the observing point, where the rangetakers have in the mean time set up the telescope tripod or director and taken the range. He sends the horseholders to mark for the flanks of the battery.

5. The two signallers lay out the telephone wire from the observing point to the position of the battery, working from the centre outwards.

6. The battery leader gallops up, followed by his signaller; the B.C. points out to him the position of the battery and the aiming point.

7. The battery leader brings the battery into action and points out the aiming point. The limbers proceed towards the position selected by the Battery Commander.

8. In the meantime the B.C. measures the target altitude and angle of depression from observing point to battery, calculates angle of sight (which is recorded by the signaller) and sends it down to the battery.) The B.C. also sends down the estimated range in yards ("angle of sight 2° elevation, range about 4000 yards.") The word *about* is used to distinguish this order from the order to fire. The object of this order is to secure that the guns are elevated to about the firing elevation while the line is being laid out. With goniometric sights this is unnecessary.

9. The B.C. measures the angle from the target to the aiming point, making the proper allowance for his distance to the flank and to the front of the battery either by laying his director off the target and off the aiming point, or by adding or subtracting the calculated displacement. He sends this angle down to the battery, a record of this order being kept by the signaller.

10. The battery being reported ready, the B.C. sends down the elevation (or two elevations) to the ranging section and the corrector setting to the remainder. The ranging rounds are fired, and the B.C., holding his deflection scale at arm's length, measures the distance of the fall of the shots right or left of the target.
target.

11. The B.C. sends down the deflection correction and orders a fresh elevation or elevations. ("All guns 2° more right. 4500-4600.")

12. The B.C. orders a further deflection correction if necessary, and a fresh elevation. If the target is bracketed he orders a fuze ladder. "Remainder 4600, time shrapnel. 4600, 4700."

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13. On the result of the two verifying rounds the B.C. gives the elevation for the fuze ladder "Remainder 4600, one round battery fire 3 seconds."

14. Should the target be visible guns, the B.C. orders "corrector — one round battery fire 10 seconds." He notes the error of each gun, which is recorded by the signaller. He sends down the six corrections thus: "Number 1, line. Number 2, ¼° more left. Number 3, ½° more left. Number 4, doubtful. Numbers 5 and 6, line. Fire Number 4 again."

15. Number 4 gun having been fired again, the B.C. gives "Number 4, ¾° more right. Section fire 10 seconds."

16. To switch on to a fresh target, the B.C. orders "Empty guns. Angle of sight 1° elevation. All guns 7° more right. Ranging section 3800-4100."

The procedure is then as before, except that, the error of the day of the fuze having been determined, there is no necessity to fire a fuze ladder.

The above procedure may appear complicated. But if every detail of it has been so thoroughly practised as to make it a matter of routine, like harnessing up a horse, the whole operation will go off smoothly and with less mental strain to all concerned than one of our old drill evolutions, such as "change front right back on number 4."

There is one point which should not be forgotten, and that is the concealment of the B.C. and his Staff—the "brain of the battery." Under ordinary tactical conditions the enemy will probably be able to locate the battery, though invisible, within say a quarter of a mile. The enemy will keep a bright look out for the B.C. and will fire on any likely observing point. It is therefore advisable for the B.C. not only to keep under cover, but to avoid selecting any *conspicuous* observing point near the battery. It may be found to conduce to the steadiness of the battery staff, and the accuracy of the Major's calculations, if a dummy observing station, with three handspikes for a tripod, be set up on the distant flank of the battery. The dummy tripod should not be set up in front of other troops, as this would tend to disturb the harmony which should prevail between the different arms.

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APPENDIX TO CHAPTER XXIII.

ANGLE OF SIGHT TABLE.

By Captain F. C. Tyler, R.F.A.

(This Table has been printed in the R.A. Journal, and copies may be obtained from the Secretary, R.A.I.)

To find the angle of sight when using an observing party.

RANGE.	¼	½	¾	1	¼	½	¾	2	¼	....	¾	4	¼	½	¾	5	Angle of Sight.
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Difference in height for any Angle of Sight at any Range.
1550	20	40	60	81	191	122	142	163	183	....	305	325	345	366	386	406	
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
3025	40	79	119	159	198	238	278	317	356	....	595	633	673	712	752	792	
3050	40	80	120	160	200	240	280	319	359	....	600	639	679	718	758	799	

Ranges are in yards. Differences in height are in feet.

TO USE THE TABLE.

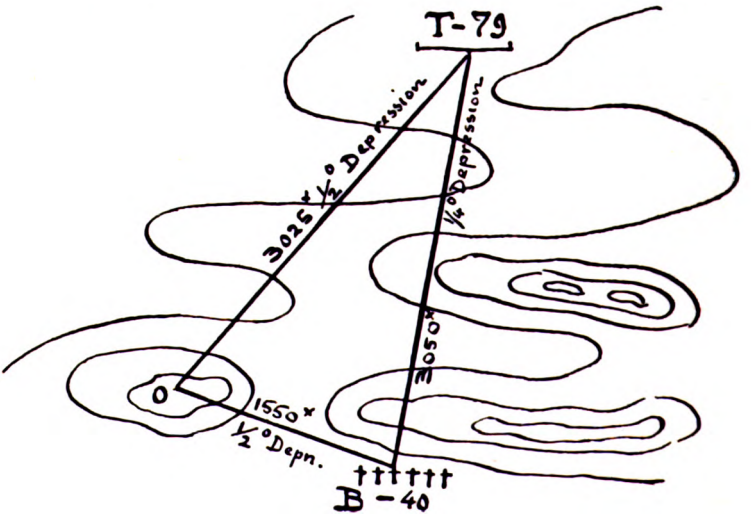
Take the angle of sight from O to B and T.

The ranges OT, OB, and BT have been found.

By reference to the table the differences in height between O and T, and O and B, are found.

This gives the relative heights of B and T.

Another reference to the table gives the angle of sight from B to T.



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Thus in the example:—

The angle of sight from O to T is — ½°; and from O to B — ½°.

The range from O to T is 3025; and from O to B, 1550.

In the line (in the table) of 3025, we find the difference in height for ½° to be 79 feet. T is thus 79′ below O.

Similarly, B is 40′ below O.

Therefore, T is 39′ below B.

The range from B to T is 3050.

Against 3050 (in the table) we find a 40-foot difference (the nearest number) is that corresponding to an angle of sight of ¼°. This will be depression in this case.

It is assumed that any angle of less than ¼° may be disregarded in practice.

LAYING BY THE SUN.

The following method of laying guns by the sun was used by the Russians in Manchuria. It may occasionally be useful when it is neither possible to see the guns nor to see the battery leader's director from the observing station.

Set the director at zero, and align it on the target. Unclamp, traverse the sight-bar till the shadow of the backsight falls in line with the foresight, and read the angle. Send down this angle, plus or minus the displacement correction, to the guns, and let the guns lay by the shadow of the backsight of the gonio. sight in the same way and at the given angle.

Then the guns will be pointing at the target. Each gun can now pick up an aiming point. The guns must be ready to lay at once when the angle is sent down, as the sun moves ¼ degree per minute. This method can be only used when the sun is fairly low in the sky. The moon or a bright star can be used as an aiming point in the same way.

Laying on a Searchlight is easy if a piece of thin paper be held close in front of the backsight notch. The shadow of the foresight is visible through the paper.

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CHAPTER XXIV.

RANGING.

Theoretical Process.

To find the range, two rounds are fired at elevations differing by 300 yards; if one of these falls short of the target and the other beyond it, the target is said to be bracketed, and these two rounds then form the *long bracket.* Two more rounds at intermediate elevations of 100 yards are fired. The target must be included either between these two rounds or between one of them and one of the first pair. This gives the *100 yards bracket.* This bracket is verified by firing two rounds, one at the shorter and one at the longer limit. A final correction of 25, 50, or 75 yards above the lower limit will then give the range within $12\frac{1}{2}$ yards.

Should any one of the bracketing rounds strike the target, the verifying rounds should immediately be fired at that elevation.

Theory of Ranging.

The above is the theoretical process of ranging. In practice it does not work out so simply.

The theory of ranging is based on the probable rectangle of the gun. (See Chapter XV.)

Taking the length of the 50% rectangle of a field gun at 3000 yards as 30 yards, then the total rectangle is 120 yards long. That is, a correctly layed round may fall anywhere between 2940 yards and 3060 yards from the gun. So that if the correct range of the target be 3050 yards, a shot fired at 3000 yards might pitch beyond the target, leading the B.C. to believe that the true range is less than 3000 yards. If, on the strength of this, the B.C. proceeds to 2800, 2900, 2950, and 2975 yards, his shot will still be falling 75 yards short of the target.

Or to take another instance—

Suppose the B.C. opens fire with his ranging section at 3000 and 3100 yards, he may get the former pitching over the target and the latter short. This may not improbably cause the S.C., if inexperienced, to find fault with his layers, spoiling their laying and perhaps rendering the whole series ineffective.

Principles of Ranging.

From these two examples we may deduce the first principles of ranging:

A. Open fire at two elevations differing by not less than the length of the total rectangle of the gun.

B. Never trust a bracketing series of which only one round is plus or only one round minus.

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With regard to "A," it must be remembered that under service conditions the total rectangle will probably be twice as long as the theoretical total rectangle of the gun. This is due to inevitable small errors in laying, and to difficulty in distinguishing the target. F.A. Training therefore wisely ordains that under ordinary circumstances the interval between the first two ranging rounds is to be 300 yards.

With regard to "B," we have seen that it is advisable to repeat a single plus round or single minus round, even if clearly observed, before finally accepting the result of a bracketing series. This is absolutely necessary when observation is at all indistinct. It is a common error to suppose that any mistake in the long bracket will necessarily be discovered when the two verifying rounds are fired. At a service target, such as an irregular line of infantry lying in the grass, it is extremely difficult to determine whether a group of verifying rounds, pitching near the target, is under or over, and the consciousness of this difficulty is apt to make a Battery Commander assume, against his better judgment, that his verifying series is successful, though the soundness of his long bracket may be more than doubtful. Of two evils it is better to expend time and ammunition on getting a thoroughly reliable long bracket, and then to "jump" the range and fuze, than to hastily assume the accuracy of the long bracket and have to expend twenty rounds in correcting it. The latter procedure is by no means uncommon at practice camps, when it is passed over with a few pungent remarks from the camp staff; on service it might lead to the loss of a battle.

Creeping.

Suppose the Battery Commander orders "both guns 2300," and observes both rounds a long way short; if he then proceeds successively to 2600, 2900, 3200, 3500 (over), 3400, 3200 and 3250, this is called *creeping*.

Creeping is less common since F.A. Training, 1903, has laid down that the normal interval between the original ranging rounds is to be at least 300 yards. It involves a great waste of time and ammunition. In the above case the B.C. would have done much better to make a 1000 yards bracket, proceeding to 3300, 3000, 3300 (repeated), 3100, 3200, and 3250.

When one round of the long bracket is clearly observed to fall close to the target, it saves time to make a 100 yards bracket, *repeating that round.* This is laid down in F.A.T. Thus if 2900 is observed just over, the next two rounds should be 2800—2900. Or if 3000 is observed just short, the next two should be 3000—3100.

Special Conditions.

It very frequently happens that all shell which fall (say) over the target are lost to view. This would happen, for instance, in firing at guns at the edge of a wood. In such a case there is nothing for it but to get a reliable pair of rounds short, "creep" forward till the shell again begin to disappear, and then verify.

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Ranging Traps.

These are of many kinds. But the commonest and most dangerous trap is a deep hollow in front of the target. By the time the smoke of the bursting shell has risen to the level of the line of sight it is so thin that the target shows through it, and the appearance is very much as if the shell had burst over.

Another common trap is a ridge rising to the level of the target, say 200 yards in front of it, with an intervening hollow. Shells which fall into this hollow disappear and are judged over, while shells bursting on the ridge appear to be "range."

No "dodge" has ever been invented to avoid such traps. There is nothing for it but patient and conscientious adherence to the greatest of all ranging rules, which may be thus stated—

DO NOT ATTEMPT TO OPEN FIRE FOR EFFECT TILL YOU HAVE ESTABLISHED A THOROUGHLY RELIABLE LONG BRACKET.

FIG. 85.

Study of Ground.

Although there is no "dodge" which gets over the difficulty of ranging on a deceptive target, it is often possible to infer the existence of a trap from an intelligent study of the ground. Thus, in the annexed rough sketch, it is obvious that a hollow runs behind the ridge with the pine trees on it. An old hand at ranging would immediately recognise the possibility of the guns being on the distant ridge instead of the nearer one. He would range upon the right-hand gun (because the hollow is presumably shallower there); he would see that the subaltern of the ranging section got his line accurately; and he would require at least two verifying rounds distinctly observed "over" before going to time shrapnel. In a case like this, if ranging with the right section, it would not be amiss to send the left section subaltern out to the flank to observe, and so check the battery commander's observation.

RANGING WITH TIME SHRAPNEL.

This is only applicable to equipments in which the setting of the fuze is always that due to the range, as modified by the *corrector* described below.

If, in Fig. 86, the corrector be lengthened till all the fuzes burst on a plane about 10 feet from the ground, then the lower edge of each cloud of smoke will either obscure the target or be obscured by it, thus enabling unders and overs to be distinguished even more readily than when the shell are burst on graze.

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This can only be done with fuzes which burn regularly, since high bursts are useless for observation. Time-shrapnel ranging with a bad fuze would entail a great waste of time and ammunition.

An inherent defect of the system is that the appearance of the burst gives no clue to the actual distance over or short of the target, since two bursts in air 500 and 50 yards short look much the same.

On the other hand, ranging with time shrapnel does away with all complications due to the nature of the ground at the target, such as the "ranging traps" already referred to. It is especially useful where the ground falls away steeply behind the target, rendering grazes over difficult to observe.

After several years' experience, ranging with time shrapnel has been adopted by the French artillery as their normal method; and in this the French have been imitated by several other nations which have lately re-armed with quick-firing guns.

FINDING THE FUZE.

Continental Methods.

In all Continental field equipments each nature of gun has a special fuze, graduated in metres of range. When changing to time fuze, the fuze is simply set to the range, and corrected if necessary by a device called a "corrector" which alters the apparent reading of the sight without affecting the elevation given. A somewhat similar system has been adopted in England.

English Method.

The dial upon which the elevation given to the gun is set has an inner circle upon which the length of fuze for each range is marked. The inner dial can be shifted with respect to the outer so as to alter the reading of the fuze for any range. The amount by which the inner dial is shifted is shown on a *corrector scale*, graduated from 0 to 100, 50 being in the centre, so that the normal setting is 50. The Battery Commander does not concern himself about the actual length of fuze used, since the fuze is always set to the figure opposite the range at which the gun is firing. But if the fuze is too long or too short, he can adjust it by ordering the fuze-dial to be shifted so many divisions of the corrector scale.

When once the setting of the corrector to give the proper length of fuze for any given range has been determined, then, so long as the atmospheric conditions remain the same, the same setting will give the correct length for any other range.

The Fuze Ladder.

After detailing the ranging section, the Battery Commander orders the remaining 4 guns to set their corrector scales at lengths decreasing by ten divisions, giving 4 fuzes of different lengths. When the 100 yards bracket has been found, these 4 guns are fired, usually at the lower elevation of the bracket. From these four fuzes the B.C. selects the most suitable, thus obtaining the corrector setting for the whole battery.

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In changing on to a fresh target at direct fire there is no necessity to fire a fresh fuze-ladder, since the corrector setting holds good for any range. This also applies to indirect fire, provided that the angle of sight has been correctly determined.

Principles of Fuzing.

Whatever be the special method adopted, certain fundamental principles of fuzing must be borne in mind. The chief of these is that it is never safe to accept a fuze as correct without "going forward for a graze." If the fuzes are all bursting in air, it may mean that the range is short and that the shell are bursting hundreds of yards short of the target, where they are quite ineffective. By lengthening the fuze till 3 or 4 grazes are obtained, any error in range will be detected, and the fuze may then be shortened again till it gives only 10 per cent. of grazes. It is not necessary to increase the fuze for the whole battery, as this would make the fire temporarily ineffective. The ranging section, or even a single ranging gun, is sufficient to verify the fuze.

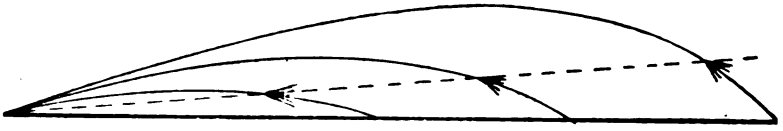

FIG. 86.

Typical Height of Burst.

The next principle is, that provided the range has been correctly found the height of a shell burst at the proper distance from the target corresponds to a given angle above the line of sight equal to about $\frac{3}{1000}$ or 11 minutes of elevation. The approximate truth of this may be proved mathematically, but it is sufficiently evident on inspecting Fig. 86. Thus, at a range of 5000 yards the slope of descent of the 15 pr. Q.F. is 1 in 3, so that a shrapnel bursting 50 yards short would be 50 feet high. The height given by the $\frac{3}{1000}$ rule is 45 feet, corresponding to a burst 45 yards short of the target. Similarly at 3000 yards the height by rule is 9 yards, which, with an angle of descent of 1 in 8, gives a burst 72 yards short of the target.

In the French telescope a horizontal line across the field marks the $\frac{3}{1000}$ angle, so that it can be seen at once whether the shrapnel are bursting correctly; if not, they are regulated by the "corrector." In our equipment the height of burst may be observed by elevating the battery telescope (or Scott's sight, if in use) 10 minutes above the target.

Shallow Targets.

It is sometimes supposed that it is correct to burst shrapnel extra short when the target is thin and wide, as a line of extended infantry. This, however, is hardly borne out by arithmetic. Suppose a line of skirmishers advancing at 3000 yards, the vulnerable surface of each man being $1\frac{1}{2}$ yards high and $\frac{1}{2}$ yard wide, or .75 yard, which is a liberal estimate. Then the most economical effect will be produced if the dispersion of the bullets is such as to allow one bullet to each man. The "typical height of burst," 72 yards short, gives 1.35

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bullets to each man; to get 1 bullet per man the shell should burst 84.75 yards short. For a line of men kneeling, each presenting .375 yards of front, the shell should burst 58.8 yards short. At shallow targets, it is only when firing at men erect and fully exposed that the best distance of burst exceeds that corresponding to a height of $\frac{3}{1000}$ of the range, and such instances are of rare occurrence.

Deep Targets.

A target which frequently occurs on service is a space of ground, say 400 yards deep, irregularly covered with advancing infantry. Independently of searching for depth by varying the elevation, it is necessary to sweep the ground with bullets as thoroughly as possible. In order to do this we must burst the shrapnel high enough to keep the bullets—or some of the bullets—off the ground till their effective velocity is expended. This will be better understood on referring back to Figs. 66 and 67, the two illustrations of the shrapnel cone. Fig. 66, representing the burst of the 15 pr. B.L. shrapnel at 3000 yards, may be taken roughly to represent also the burst of high-velocity Q.F. shrapnel at 4000 yards. When burst at a height of $\frac{3}{1000}$ as at S_1, we do not get the full advantage of the depth of the cone; the maximum depth of ground swept is obtained by shortening the fuze till the burst is 65 feet high, as at S_8, after which the depth falls off again.

In Fig. 67, representing the burst of a modern high-velocity shrapnel at 3000 yards, we see that, thanks to the flatness of the trajectory, the "hauteur type" of $\frac{3}{1000}$ is sufficient to give full effect to the depth of the bullet-cone. In this case nothing is gained in depth by shortening the fuze to raise the point of burst, and when raised to 100 feet, which corresponds to 330 yards short, the bullets lose their effective velocity before reaching the target.

Raising the Point of Burst.

It is also possible to gain increased depth of effect by raising the point of burst without shortening the fuze—in other words, by giving increased elevation. Thus in Fig. 67, after having found the fuze for the $\frac{3}{1000}$ height of burst, the trajectory might be raised 30 feet or 12 minutes, causing $\frac{3}{4}$ of the bullets to fall over the target and $\frac{1}{4}$ short. This expedient is a dangerous one and should not be adopted unless the strikes of the bullets can be observed. Moreover the increased effect can only be obtained at the expense of the effect on the front line of skirmishers fired at, which effect is a maximum when the trajectory (or rather the axis of the bullet-cone) passes through the target.

Shielded Guns.

The object is to sweep the ground behind and around the guns with bullets, so as to prevent any movement in the battery, and at the same time to get as many direct hits as possible. The range and line for each gun must be carefully corrected and the fuze lengthened till about 80 per cent. of shell burst on impact. It must be remembered that a percussion shrapnel which bursts as it passes through a gun-shield will appear to be over.

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The best tactical method of attacking shielded guns is by the concentration of the fire of dispersed batteries. For though a shielded gun may withstand frontal fire for a long time, it will stand a poor chance when the shells begin to come in from three directions at once. Another method which may be adopted by the stronger party is to push forward single sections to within close range, in the hope of knocking out the enemy's guns by direct hits, while the remainder of the artillery covers the advance of these sections and keeps the enemy fully employed.

The Distance of Burst.

The distance of burst is directly proportional to the density of the bullet-cone and to the vulnerable surface exposed by each man of the enemy.

This is shown as follows—

Take a typical shrapnel, giving at 3000 yards a bullet-cone containing 300 bullets, with an angle of opening of 1 in 5. The "hauteur type" of $\frac{3}{100}$ of the range gives a burst 72 yards short; then the cross-section of the cone, at 72 yards from the burst, will be 14.5 yards in diameter, with an area of 165 square yards, and a "density" of 1.8 bullet per square yard.

Let this shrapnel be burst 72 yards short of a line of skirmishers (interval immaterial) of which each man presents a vulnerable surface 1½ yards high by ½ yard wide, or .75 square yard. (This, as will be seen, is a liberal estimate.) Then if the shrapnel gives a good pattern—that is, if the bullets are uniformly distributed over the cross-section of the cone—each skirmisher will be hit by 1.8 × .75 or 1.35 bullets on the average, which is a waste of 35 per cent. of bullets. Supposing the skirmishers closed to one man per yard, then 14.5 skirmishers will be hit by 20 bullets.

Now let the shell be burst 84.75 yards short instead of 72 yards; then the cross-section of the cone will be 225 square yards, with a density of 1 bullet to .75 yard. The diameter of the cone will be 17 yards nearly, providing one bullet apiece for 17 men, instead of 1.35 bullets apiece for 14.5 men as before.

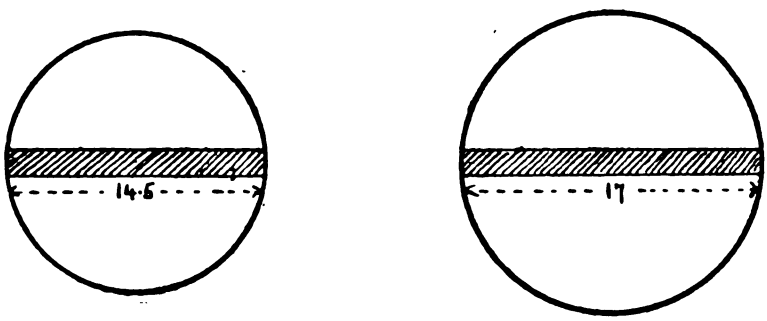

FIG 87.

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Maximum Effect.

The above is the maximum theoretical result which can be obtained by suiting the point of burst to the given condition, which require a density of 1 bullet to .75 square yard. It will be observed that this maximum result is nothing like 35 per cent. better than the 72 yards result, in which 35 per cent. of bullets were wasted by putting more than one bullet into each man. The reason for this is shown by Fig. 87. In the left-hand figure, representing the cross-section of the cone at 72 yards, we have a band 1½ yards high extending across a circle 14.5 yards in diameter, and occupying 0.13 of the area of the circle; in the second figure we have a band of the same height, across a circle 17 yards in diameter, occupying only 0.1 of the area. In the second instance we therefore utilize a less number of the bullets contained in the shrapnel, namely, 17 as against 20, although we apply them more economically.

When firing at a target of no depth, such as a single line of infantry, the proportion of effective bullets falls off rapidly as the distance of burst required to produce the required density is exceeded. It is therefore usually advisable to burst the shrapnel too close to the target rather than too far from it.

Area of Targets.

The following figures are given by Gen. Langlois as representing the vulnerable area of a soldier, not including his clothing or equipment:—

Infantry soldier, standing, front view ...	0.57	square	yard.
,, ,, ,, side view ...	0.33	,,	,,
,, ,, kneeling, front view ...	0.38	,,	,,
,, ,, lying down, front view	0.19	,,	,,
Horse, front view	1.0	,,	,,
,, side view	1.90	,,	,,
Cavalry soldier, front view	1.35	,,	,,
,, ,, side view	2.16	,,	,,

Practical Rules for Fuzing.

We may now enunciate some simple practical rules for fuzing:—

1. Start the fuze-ladder at a corrector setting at least 200 yards short of the fuze laid down for the range. No effect, and no information as to the proper length of fuze, is obtainable from a ladder of fuzes all bursting on graze.

2. Open section fire with the last fuze of the ladder which bursts in air.

3. Verify by lengthening the fuze of at least one gun till grazes are obtained, and correct the fuze till it gives 5 to 10 per cent. of bursts on graze. This length, if the range has been correctly found, corresponds to a height of burst of $\frac{3}{1000}$ of the range.

4. At a deep target set the fuze to burst 50 yards shorter than the normal setting as above determined.

5. At shielded guns lengthen the fuze till it gives 75 per cent. of bursts on graze.

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6. At a scattered target such as an extended line of skirmishers, do not attempt to cover an increased front by shortening the fuze, but burst your shell at the most effective distance—namely, close up—and obtain increased lateral spread by sweeping combined with increased rate of fire.

7. At scattered targets and at shielded guns only a small proportion of men hit per shell can be expected. Therefore do not hesitate to use the full power of the Q.F. gun, and put in a number of shell sufficient to secure the desired result.

Velocity of Sound.

It may be occasionally useful to know that the report of a gun travels at about 400 yards per second. If it be possible to observe the number of seconds between the flash and report of an enemy's gun, this number multiplied by 4 will give the range in hundreds of yards.

Similarly, if another battery be firing at the enemy's infantry, the time between the report of the gun and the visible burst of the shrapnel will give the fuze the battery is using, and the time between the smoke and report of the shrapnel will give the distance.

The above rule rather over-estimates the range.

If a pendulum 11.41 inches long be hung from the hook of the telescope tripod, then each single oscillation counted between flash and report will correspond to 200 yards of range. Similarly, a pendulum 2.85 inches long will beat once for every 100 yards of range. The length of the pendulum is measured from the point of support to the centre of gravity of the pendulum.

As might be expected, the velocity of sound is considerably modified by wind, and the above methods are only to be trusted on a moderately still day.

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CHAPTER XXV.

FIELD HOWITZER FIRE.

General Principles.

The object of the existence of a field howitzer is to engage a standing target such that field guns cannot reach it. The target may be a position held by troops keeping under cover, or by troops entrenched, or by troops in field-works with overhead cover. Or the target may be shielded artillery, with detachments protected against direct shrapnel fire. In none of these cases is any advantage to be gained by coming into action in the open, and we may therefore safely say that the normal method of opening fire for howitzers is from a covered position.

The Choice of a Position.

As has been pointed out, there is no such thing as a position offering cover from fire to a field gun, since the angle of descent of the enemy's shell is greater than the angle of elevation of our own. But this does not apply to howitzers. A howitzer with an angle of elevation of 45° can fire from behind a "covering mass" so steep that the enemy's bullets which clear the crest pass harmlessly overhead. Such covering parapets are rarely to be found in nature. But a row of houses, a high wall, or a railway embankment may often be found, affording perfect protection against anything but high-angle fire.

From a gunnery point of view, therefore, the object of the howitzer battery should be to get as close as possible behind steep cover.

Such a position has the further advantage that the battery is close up to the observing station on the crest from which its fire is regulated.

The Occupation of a Position.

The gunnery points involved have already been considered in Chapter XXI. In the case of howitzers additional stress must be laid upon one point, namely, the necessity of having the wagons alongside of the guns. A howitzer shell weighing 35 to 40 lbs. is not a handy load for a man to double 20 yards with. Moreover, when firing from a covered position the shallower the target the less becomes the likelihood of the enemy's shell finding it.

Ranging.

Howitzer shell are too valuable to be lightly thrown away, and rounds should therefore be economised in ranging. Thus when a long bracket is formed at 3000—3400 of say one shot 100 short and one 300 over, the next two rounds should not be 3100—3300 as with a field gun, but 3050—3150, probably saving two rounds at the

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expense of a little extra calculation. Such economy is the more necessary that the range must be determined with more accuracy than is required for a field gun, since the shrapnel bullets, owing to their low velocity and sharp angle of descent, only search a small area of ground.

Observation and Correction of Fire.

When a field work has to be searched with shrapnel, or a field casemate breached with H.E. shell, accurate observation and correction of fire is required, otherwise the expenditure of time and ammunition will be very great.

There are two methods of correcting fire, neither of which has yet been introduced into our Field Howitzer training.

Siege Method.

The first is that employed by siege artillery, and consists in observing the fall of each shot with two telescopes placed at least 500 yards apart and connected with the battery by telephone. Each telescope has a *graticule* or series of lines ruled in the field, each line corresponding to say one minute of angle. Suppose each telescope directed at the point to be struck; then a round is observed say 8 min. R. in the right telescope and 3 min L. in the other. These observations are telephoned to the battery, where the B.C., by means of a scale of natural tangents for the range, plots the fall of the shot on a piece of paper ruled in squares, and finds it say 63 yards over and 12 yards right.

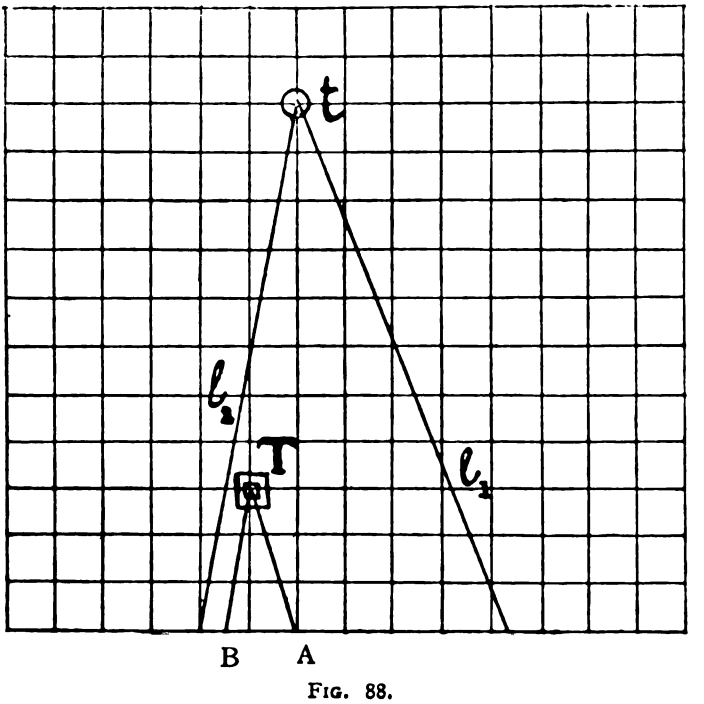

FIG. 88.

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Fig. 88 shows a chart of this kind. The range is 3600 yards, so that the natural tangent of 1 minute is 1 yard. Let T be the target, A and B the two observing stations. Then the plotting officer draws line l_1 parallel to TA and 8 yards (to scale) from it; he draws line l_2 parallel to TB and 3 yards from it, and finds the lines intersect at t. Then by measurement t is 63 yards over and 12 yards to the right of T, and the next round is corrected accordingly.

This method is only adopted for deliberate work. Once the observing stations established and plotting chart made out it is remarkably quick. But the practical delay is in measuring the distance between the observing stations, solving the triangle, and setting off the angle ATB on the chart.

Still, a field howitzer battery ought to be able to undertake siege work of this description when required, and the siege method of observation should therefore form part of its training.

Major Lyon's Method.

This method has been suggested by Major C. Lyon, R.F.A., and has the advantage of requiring no plotting. The two telescopes are set up as before, and the triangle ATB solved with the assistance of a slide rule. Then if the right observer observes the shot 10 min. R, and the left observer 5 min. L, the angle at the apex of the triangle is 15 min. smaller than the angle ATB. The B.C. is provided with a set of tables showing the difference of range corresponding to a difference of 1 minute in the angle at the apex of the triangle, for each 100 yards of range and each 10 yards of base between say 300 and 500 yards. From these tables he at once reads off the correction in range required for the next round. This method does not give the lateral error, but this is of less importance since as soon as the range is found it can be determined by direct observation.

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CHAPTER XXVI.

VISIBILITY.

(Officers are recommended to study General Baden-Powell's book on "Scouting.")

The keynote of a landscape is confusion of detail. All natural objects are irregular in shape and complex in outline. Any symmetrical object, such as a gun-carriage, tends to catch the eye at once. In Nature there are no straight lines (except the surface of water,) no circles, and no squares.

Again, there are no sharp contrasts in Nature; the colour and tone of all natural objects are infinitely varied. For this reason any object of uniform colour, such as the side of a house or the surface of a flat gun-shield, attracts attention immediately.

Lastly, natural objects do not move about. So long as a man or a horse keeps still he often escapes notice. The hunter who sits for hours waiting for a shot knows this well; he also knows that the erect figure of a man is unlike anything in nature, and carefully avoids the upright position. It was a standing order in Natal that when men were seen erect on the sky-line the troops were on no account to fire on them, as they could not possibly be Boers.

The most conspicuous feature of a landscape is invariably the sky-line. Not only does any movement or any artificial-looking object catch the eye at once, but the sky-line forms the natural point of aim for all infantry. Accordingly it is especially important for guns to avoid it, since artillery in action are more stationary than any other troops and have to remain longer under fire.

Not only symmetry of form but symmetry of order or arrangement makes for visibility. A single gun might escape notice, but six guns at regular intervals, though inividually barely visible, form a group unlike anything in Nature, and arouse suspicion accordingly.

Time of Exposure.

It takes a certain period of time for a visible but inconspicuous object to catch the eye of observers. It is therefore sound to reduce the period of exposure to a minimum, even at the expense of additional momentary visibility. Thus, if it be necessary to cross a ridge in view of the enemy, the best way is to form line under cover and let every carriage cross as nearly as possible simultaneously. If the opposite plan be adopted, and it be attempted to steal over in column of route, then the first battery may possibly get over before the enemy realises what is happening, but the batteries following are likely to suffer severely.

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Application of Principles.

We will now consider the application of the above principles to service conditions. Take first the peace-time preparations. We have already, in the English pattern khaki uniform, an admirably inconspicuous dress. When we get the new pattern harness most of the flashing metal work which we now display will disappear The colour of our guns and carriages still however leaves much to be desired, being too dark and too uniform in tint. (I do not refer to the cream-coloured paint formerly issued by the Ordnance, but to the darker "Service Dress" tint, which is practically the same as the old lead colour.) It must be recognised that guns are meant for war and not for peace, and they must be mottled, clouded, or chequered, even at the expense of smartness of appearance on a ceremonial parade. Further, the under sides of guns and carriages. being in shadow and therefore darker than the rest of them, form the most visible features of the equipment; to compensate for this all under surfaces should be shaded off to a lighter tint.*

The flat front of a gun-shield forms a reflecting surface which no amount of paint can hide. The only resource left is to break the surface by hanging gun-buckets, drag-ropes, and miscellaneous stores upon it.

In other respects the gun-shield does not on the whole add to the visibility of the gun. We all know the distinctive appearance of a gun on a sky-line, with a wheel sticking up on each side and the muzzle in the middle.

FIG. 89.

When the space between the top of the wheels is filled up by the shield, it tends to reduce rather than to increase the conspicuousness of the gun, especially if the top of the shield is humped or curved. Moreover, the shield hides any movement of the detachment, which movement often enables the gun to be located.

Visibility of the Wagon.

There is unfortunately no doubt that a wagon placed alongside the gun is more visible than a wagon down the slope behind it. This position of the wagon is however necessitated by modern conditions, and must be accepted in spite of its disadvantages. On the other hand, it has been shown in the chapter on "Accuracy of Fire" that the wagon is less likely to be struck when placed alongside the gun than when behind it. (See page 121.)

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* NOTE.—"Animals are usually dark above and light beneath, because this arrangement is exactly the opposite of what happens when light falls upon a solid body which need not be concealed. A normally-coloured animal in its normal surroundings will therefore not seem to be solid and will be practically indistinguishable at a short distance against a background of colour and of pattern similar to its own."
—Theodore A. Cook.

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But the real reason why the wagon must be placed alongside the gun is that under fire from a Q.F. battery the casualties among the numbers supplying ammunition, if they had to come out from behind their shields to bring ammunition up to the gun, would be so heavy as to stop the fire of the battery.

Smokeless Powder.

Modern nitro-powder gives very little smoke. But the broad white flash from the muzzle is conspicuously visible, especially against a dark background, which should accordingly be avoided when practicable. It has been found by experiment in France and Germany that the flash is visible over a crest when the gun is not more than 3 metres, or 13 feet, below the crest. Field howitzers firing full charge require about 20 feet of cover. The only means of concealing the flash of the guns at direct fire is by placing them behind a screen, such as a row of thinly growing trees, which permits the layers to see through while hiding the flash from the enemy. It is however the exception to find such a natural feature available.

It has been proposed to fix a shield about 2 feet in front of the muzzle of the gun, with a hole in it for the projectile to pass through. The impact of the gases on this shield would help to check the recoil, while the visible flash would be materially reduced. But the idea has not as yet assumed a practical form.

Dust.

Both when moving into position and when the guns are in action the dust thrown up often betrays the presence of the battery. On the defensive, when there is plenty of time for preparations, it is desirable to water the ground in front of the gun-muzzle.

Artificial Cover from View.

The provision of such cover can rarely be attempted except on the defensive. It may take the shape of a thin irregular screen of brushwood either in front of the guns or behind them. Bushing up a gun by sticking bushes in the wheels is difficult to do artistically and usually makes it more conspicuous than before.

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CHAPTER XXVII.

THE FRENCH SYSTEM OF FIRE-DISCIPLINE.

NOTE.—Officers are recommended to study General Rohne's pamphlet on this subject. A copy of the English translation by Major Crowe, R.F.A., has been issued officially to Artillery Brigades.

Following the introduction of the 1898 Q.F. field equipment, the French Artillery have adopted a novel system of fire-discipline intended to utilize the power of the new gun in the fullest possible manner. This system, though by no means generally approved in other countries, merits careful study by all officers of the Horse and Field.

The French Equipment.

The details of this are given in Part IV. The French battery consists of 4 guns and 12 wagons. Each gun in action has an armoured wagon-body unlimbered and up-ended alongside of it; two other wagon-bodies are also brought up, behind one of which, on a flank, the battery commander takes shelter.

The gun is a shielded Q.F. gun with steady carriage; it has a high velocity and flat trajectory. The ammunition consists of shrapnel with a proportion of H.E. shell; the fuze is set to the gun-range by a machine on the wagon, and corrected if necessary by an adjustable scale on the machine.

Fire Discipline.

The main principles of the French system are as follows: Great importance is attached to opening *effective* fire on the enemy in the shortest possible time after coming into action, in order to render his return fire ineffective. With this object in view, the range is normally found with time shrapnel, and as soon as a long bracket has been obtained it is searched from end to end by the rapid fire of all the guns, each gun increasing the elevation and fuze after every two rounds.

When the target is a wide one, each gun *sweeps* or distributes laterally as well as searching. In the first case each gun fires two rounds at each of 4 elevations; in the second, 3 rounds at each. After this opening burst of fire the range and fuze are corrected and accurate fire proceeded with until the target is completely destroyed.

Rafales.

A "rafale" or storm of fire consists of several rounds of rapid fire from each gun at the same elevation. When the range and fuze have been found the battery proceeds to slow fire (during which fuzes are prepared) alternated with *rafales* timed to take advantage of any movement of the enemy or to check any signs of recovery on his part.

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Preparations for Opening Fire.

This is not to be confounded with preparation for action. The battery usually comes into action under cover (the forward covered position being preferred) and the line is obtained with the battery telescope and pedestal sights. Even when the battery comes into action in view of the target, laying is preferably by aiming-point for line and by clinometer for elevation, The target is allotted to each gun, and the "corrector" of the fuze-punching machine set so as to give bursts at a height of $\frac{1}{1000}$ of the range instead of the normal $\frac{3}{1000}$. The distance of the target having been measured or estimated, the B.C. proceeds to range with time shrapnel.

Ranging.

Two elevations differing by 400 metres, or less at short ranges, are ordered, and a "salvo" (corresponding to the English "one round battery fire 3 seconds") is fired at each elevation.

The French regulations lay down that if only one burst out of each salvo can be observed, and if the results concur, the bracket may be accepted. If time permits, the bracket is subdivided by another salvo, giving a bracket of 200 metres.

Tir Progressif.

Starting with an elevation 100 metres less than the lower elevation of the 200 metres bracket, the B.C. orders "tir progressif." Each gun then fires two rounds of time shrapnel, fuzed to burst at a height of $\frac{3}{1000}$ of the range, at that elevation, followed by two more at an elevation and fuze increased by 100 metres, and so on till each gun has fired 8 rounds in quick succession. Thus if the bracket be 3400—3600, the successive elevations will be 3300, 3400, 3500, and 3600. The B.C. may if he chooses order intervals of 50 metres instead of 100 between the different elevations. It is stated that the 32 rounds of "tir progressif" can be fired in one minute, without setting fuzes beforehand.

Tir Fauchant.

The normal width covered by the fire of a 4-gun battery is 200 metres; if it is desired to double this width, then at the order "Fauchez" (sweep) each gun, after the first round, gives successively 3 turns of the traversing wheel left, 3 more turns left, back again to centre, 3 turns right, 3 more right, back again to centre, and so on. This procedure enables a single gun to cover a target 100 metres wide at 2500 metres.

Tir Progressif et Fauchant.

Each gun fires 3 rounds at each of four different elevations. The first three rounds are: centre, three turns left, three more left; the next are centre, three right, three more right; and so on, making 12 rounds per gun. It is stated that the 48 rounds can be fired in 1¼ minutes, without setting fuzes beforehand.

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Echelonnement.

To distribute the fire over a target each gun requires to be layed at a different angle on the aiming-point. The increment for each gun is calculated by the B.C. Suppose he makes it 5 (thousandths) for each gun; then he gives the direction to the flank gun, and orders "*échelonnez de 5*," when each gun gives 5 thousandths more deflection than the last. Thus if the deflection for the right gun is 80 on the base-plate, then No. 2 gun gives 85, No. 3 90, and No. 4 95.

Change of Target.

Since the layers do not aim at the target but at a conspicuous aiming-point, and since elevation is given by clinometer, it is unnecessary to point out the new target to them. The B.C. measures the angle from the aiming-point to the new target, and simply orders a fresh direction and a fresh clinometer elevation.

Fire at Moving Targets.

In the case of a small rapidly-moving target it may be necessary to lay direct on it. But the normal procedure is to sweep the ground over which the target is advancing with "*tir progressif.*"

Deliberate Methods.

When immediate effect upon the target is not required, and when accurate ranging is of consequence, the older methods are followed. The target is bracketed and the bracket subdivided to 50 metres and checked by verifying salvoes. Either percussion shrapnel or, preferably, time shrapnel with fuzes set to burst close to the ground is used. Of the two, time shrapnel is considered the more easy to observe.

Registered Areas.

During any pauses in the action, ranging rounds are fired at spaces of ground on which troops may appear, and the direction, elevation, and fuze for such areas are recorded or "registered." On the large scale, batteries or even brigades (*batteries de surveillance*) are told off to watch suspected areas, ready to search the ground with *rafales* should an enemy apppear. Such batteries are usually kept ready in action in the "forward covered" position, just behind the crest line or other cover from view.

MERITS AND DEMERITS OF THE FRENCH SYSTEM.

Duties of the Battery Commander.

The first point that occurs to the student of the French regulations is the amount of work required to be done by the battery commander before opening fire. In addition to dealing with the usual difficulties of locating the target and selecting his position, he has to choose an aiming-point such that all the guns can see it, measure the angle between target and aiming-point, calculate the extra deflection for each gun, measure the angle of sight, estimate the range, point out

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the aiming-point, and order the "échelonnement" of deflection. The Battery Commander must evidently be well up in his work and be capable of doing arithmetical calculations rapidly and correctly under fire.

Most of the B.C.'s preliminary work can however be done before the battery comes up, so that if he rides a mile ahead of his battery he has ten minutes to make his calculations.

The French battery commander has several points in his favour as compared with his English confrère—

His battery of four guns is much easier to handle and control than a six-gun battery.

The flat trajectory of the French gun minimises the effect of errors in ranging.

Errors in clinometer laying are less frequent than those which occur with open sights; the latter are principally due to the layers failing to locate the target.

Duties of the Gunners.

The French gun-layer has to handle a complicated pedestal sight. But apart from this his duties are simpler than those of the English gunner, and afford less scope for making mistakes. The tendency of the French system is to throw all the head-work on the highly-trained battery commander, and to give the gunner nothing to do but to obey simple orders. The apparently complicated "tir progressif et fauchant" is not an exception to this rule, as the gunner's procedure is purely mechanical, requiring no reasoning, and even if he makes a few mistakes it is of no great consequence.

French Method of Opening Fire.

A series of *tir progressif et fauchant* consists of 48 shapnel, each containing say 260 effective bullets out of 300. The effective depth of the bullet-cone being 300 metres, these 12,480 bullets are distributed over a space 600 metres long by 200 wide, the bullets being thickest in the centre of this area. This gives .104 bullets per square metre of ground. The angle of descent of the shell being 1 in 10, or nearly 6 degrees; then the mean angle of descent of the bullets will be about 8 degrees or 1 in 7¼ (vide illustration of French shrapnel cone). Therefore the number of hits on a vertical surface 1 metre square will be 7.25 × .104 or 0.75. Taking the average surface of a man alternately lying and advancing at ¼ square metre, this gives .188 bullets per man or about 1 bullet to 5 men. That is, of any troops, not under cover, in the area covered by the *tir progressif* one man in 5, or 19 per cent., will be hit. If there are any horses in the area, then 75 per cent. of the horses will be hit. This is on the assumption that the bullets are evenly distributed, and that none are wasted by putting two bullets into one man. But even at the lowest estimate the probable percentage of hits represents a crushing effect upon any troops other than shielded artillery within the fire-swept area. And if the artillery be caught coming into action, or limbering up, the effect will certainly be to put the battery out of action for some time.

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Conclusion.

To a gunner accustomed to other methods, unbiassed criticism of the French system is exceedingly difficult. It is believed however that the following conclusions will be accepted as safe by most officers of the Horse and Field:—

1. Good or bad, the French special methods do not preclude the use of the older and slower systems of ranging. They invest the Battery Commander with additional powers, to be used or not as he may think fit. Therefore the French methods should be embodied in all future systems of F.A. fire discipline.

2. *Tir progressif* and *tir fauchant*, Anglicé searching and sweeping, should be reduced to a mechanical drill requiring no thinking on the part of the gunners, so that the B.C. can apply either or both combined by a single word of command. This has now been done in our own service.

3. Most English officers will agree that direct laying, especially when assisted by a telescope, is preferable to clinometer and aiming-point for the support—especially the close support—of the infantry attack; and that the deflection necessary for distribution over a target of given angular front should be given by the Battery Leader when the Battery Commander himself is not actually present in the battery.

4. The French system of setting the fuze to the gun-range and adjusting by a corrector scale on the range-dial is quicker, easier, and less liable to mistakes than the (1904) English method, and we have done wisely in adopting it.

5. Finally, there can be no doubt that the practice of registering the range and fuze of all probable targets is thoroughly sound. And it may be added that it will frequently be desirable to detail one gun of the battery to carry this out, even while engaging another target, provided that it is possible to keep up the proper tactical rate of fire with the remainder of the battery.

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CHAPTER XXVIII.

THE ANALYSIS OF PRACTICE REPORTS.

This should be systematically carried out after every day of practice, the results obtained being of great use in discovering defects of materiel and bad laying or fuze setting. The layers and fuze-setters will certainly do their work more carefully if they know that they will be brought to book for any errors they may make.

We will select for analysis a series fired at a long range and difficult target. The series chosen is by no means an ideal one, being marred by several mistakes on the part of the battery commander and others. (See Extract from Practice Report.)

In the first place, the B.C., believing in his range-takers, began at a range more than 600 yards short of the real distance. He was fortunate not to lose rounds 1 and 2 altogether. Having observed them very short, he should have made a bolder bracket than 300 yards, to 4000 or even to 4500 yards, and so have saved time and ammunition, instead of uselessly repeating 3800 and 4100. Next, at round 7, he was unlucky in getting one round barely over, at the extreme limit of the "sheaf of fire," and made things worse by wrongly observing round 10, which he took to be over instead of short. Rounds 9 to 14 show the pernicious influence of badly-conducted battery gun-drill. It is so easy when firing without ammunition to assume that each shot falls at the spot intended, and is always correctly observed. Evidently the B.C., after round 7, jumped to the conclusion that he had got his bracket, and rounds 9 and 10 are merely a formality to satisfy his conscience.

It is not till rounds 13 and 14, the two last of the fuzing series, that the B.C. realises that his range is short. Instead of using the ranging section, he orders a fresh "ladder" of fuzes at 4300, hoping to get his two grazes and possibly to produce some effect on the target. This is all right as far as it goes, though he would have had time for two more rounds at 4300 from the ranging section while the fuzes were being set. The B.C.'s further procedure is sound; he opens section fire at 4250 with rather a long fuze, hoping to get some more grazes; he does get them, and corrects to 4225 and corrector 40, which is a fairly good elevation. As he was engaging shielded guns, the B.C. should have lengthened his fuze to give 75% of bursts on graze.

The next step is to analyze the figures of the practice report.

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Full

No. of round.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

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Take the first round, layed at 3500 and marked 700 yards short; if it had had 700 yards more elevation it would have reached the target; therefore, according to this, the correct range should be 4200 yards. Write down the corrected range for each shot that grazes, and we have the following list:—

ANALYSIS OF PRACTICE REPORT.

No. of Round.	No. of Gun.	Elevation.	Judged by Range Party.	Corrected Range.	Error.
1	2	3500	— 700	(4200)	+ 40
2	1	3800	— 500	(4300)	— 60
3	2	3800	— 400	4200	+ 40
4	1	4100	— 200	4300	— 60
5	2	4100	— 150	4250	— 10
6	1	4400	+ 100	4300	— 60
7	2	4200	+ 10	4190	+ 50
8	1	4300	+ 80	4220	+ 20
9	2	4100	— 120	4220	+ 20
10	1	4200	— 10	4220	+ 20
11	3	4100	Premature		
14	6	4100	— 300	(4400)	— 160
15	3	4300	+ 30	4270	— 30
16	4	4300	+ 60	4240	0
19	1	4250	+ 10	4240	0
22	6	4250	+ 100	(4150)	+ 90
23	3	4250	+ 10	4240	0
27	6	4250	— 130	(4355)	— 115

Mean range 4240 yards.

The 50% rectangle for the 18 pr. Q.F. gun at this range is 35 yards long; therefore the 100% rectangle, into which all well-layed rounds should fall, is 140 yards long. Any of the above rounds which cannot be fitted into this rectangle must be struck out as unreliable. We may discard Nos. 1 and 2 as being too short for the range party to judge accurately. Of the remainder all but Nos. 14, 22, and 27 will fit into the rectangle. Eliminating these, we have 12 rounds left. Take the mean of these by adding together and dividing by 12, and we have 4240 yards, showing that the B.C. finally found the true range within 15 yards.

This range of 4240 yards is styled *the mean range as found by the guns.*

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On comparing this with the corrected range it will at once be noticed that round 14 was badly layed. Further, we see that No. 6 gun was shooting differently from the others, the errors being — 160, + 90, and — 115. This is very irregular shooting. The left section subaltern accordingly proceeds to test his guns before gun-park inspection the same evening. Both being carefully laid on a distant object, he applies the clinometer and finds that No. 6 gun is pointing 17 minutes higher than the other. This, on examination, is found to be due to the drum having slipped, and is soon set right. But this does not exonerate the White layer, who is very properly wheeled into line and told that he will be sent back to the wagon if he lays so badly again. He admits to a circle of friends in the canteen afterwards that "he knew the old girl was throwing a bit high, and tried to keep her nose down!"

Next for the fuzes.

Taking the rounds fired at 4225, corrector 40, we have:—

Round.	No. of Gun.	Position of Burst.	Error.
25	2	— 40 A	+ 6
26	1	— 55 A	— 9
27	6	(—130 G)	?
28	3	— 45 A	+ 1
29	4	— 30 A	+16
30	5	— 60 A	—14
31	1	— 50 A	— 4
32	2	— 50 A	— 4
33	6	(+ 70 A)	(+ 116)
34	3	— 40 A	+ 6

Eliminating rounds 27 and 33 as irregular, we have 8 rounds left to go upon. The mean point of burst is 46 yards short, and the average error only 7½ yards, which shows that the fuze-setting was good, in spite of one badly-set fuze (again) at No. 6 gun. The last error is one which frequently occurs: the No. 1 was puzzled by the queer shooting of his gun, and his anxiety naturally infected the detachment, with the result that the fuze-setting number began to lose his head and the fire-discipline slackened. All the trouble would have been avoided if the Section Commander had tested his sights on the previous evening.

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Part IV.

MODERN Q.F. EQUIPMENTS.

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...ve.	Norway 1900.	Portugal 1904.	Roumania 1904.	Russia 1903.	Spain 1906.	Sweden F.A. 1902.	Sweden H.A. 1900.	Switzerland 1903.	Turkey 1904.
5	2.95(5)	2.95	2.95	3	2.95	2.95	2.95(6)	2.95	2.95
4	14.3	14.3	14.3	14.71*	14.3	14.3	14.3	14	13.2
)	280	294	295	300*	294	295	295	210	270
	42	45	42	43	45	42	42	36.3	42
	No.	?	Yes	Yes	?	No	No	Yes	Yes
0	1640	1640	1640	1930*	1640	1640	1640	1590	1590
3	266.6	266.6	266.6	380	266.6	266.6	266.6	245.3	230
:o	N.G.	Nitro	?	Nitro	Nitro	Nitro	Nitro	Nitro	N.G.
l	6.5	6.67	7.37	7.85	6.67	6.66	6.8	6.48	6.9
3	19.45	21.25	21	22.5*	21.25	19.15	17.43	19.75	206*
3	36	36	34.8	38.5	36	35.3	31.5	35.5	35.5
	8.0	8.84	8.6	9	8.84	7.85	See[8]	7.75	8.25
	15½	16	16	16¾	16	16	18	16	15
	3½	3	3	2¾	3	3	3	2	3
	48	50	54	40	50	54	See	53	48
"	4'6"	4'4"	4'3½"	4'4"	4'4"	4'4"	4'4"	4'3½"	4'3½"
	10	9	8.66	9	9	9	8.66	8.66	8.75
3	No	Yes	No	No	Yes	Yes	No	No	No
).	O	G	T.G.	O.P.	G	T.G.	O	O	O
	N.S.	C.S.	N.S.	N.S.	C.S.	N.S.	N.S.	N.S.	N.S.
	31	31.4	30	32*	31.4	30.7	30	30	30
).	E.S.	S.B.	W	S.B.	S.B.	W	W	W	W
l	0.114(7)	0.2	0.236	0.2	0.2	0.187	Nil	0.167	0.1575
	P	A	P	A	A	P	P	P	P
	36	38	24	36	38	44	40	40	40
	36	38	24	38	38	48	—	48	40
	64	72	64	48	72	48	—	48	64
3	236	258	200	228	258	284	132	280	196
5	40.5	37.4	36	38	37.4	36.3	32.4	35.3	36.25
l	Nil	?	?	?	?	Nil	Nil	?	?
	6	4	4	8	4	4	4	4	6
	12	8	8	16	8	10	4	10	9
n-ond	Ehr-hardt	Schnei-der	Krupp	Putiloff	Schnei-der	Krupp	Krupp	Krupp	Krupp

is is the 7.5 cm. Krupp gun now under trial. Figures doubtful. The present Italian field batteries have 6 guns and 7 wagons.
.e shield weighs only 56 lbs. and is carried on the wagon.
ıe H.A. Gun is not a gun-recoil, but a spring spade equipment.

the gunners.

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Page 211.—Table of Field Guns.—The new Italian gun is now reported to fire a shell of 14.71 lbs. with M.V. 1590 fs. and M.E. 258.5 foot-tons.

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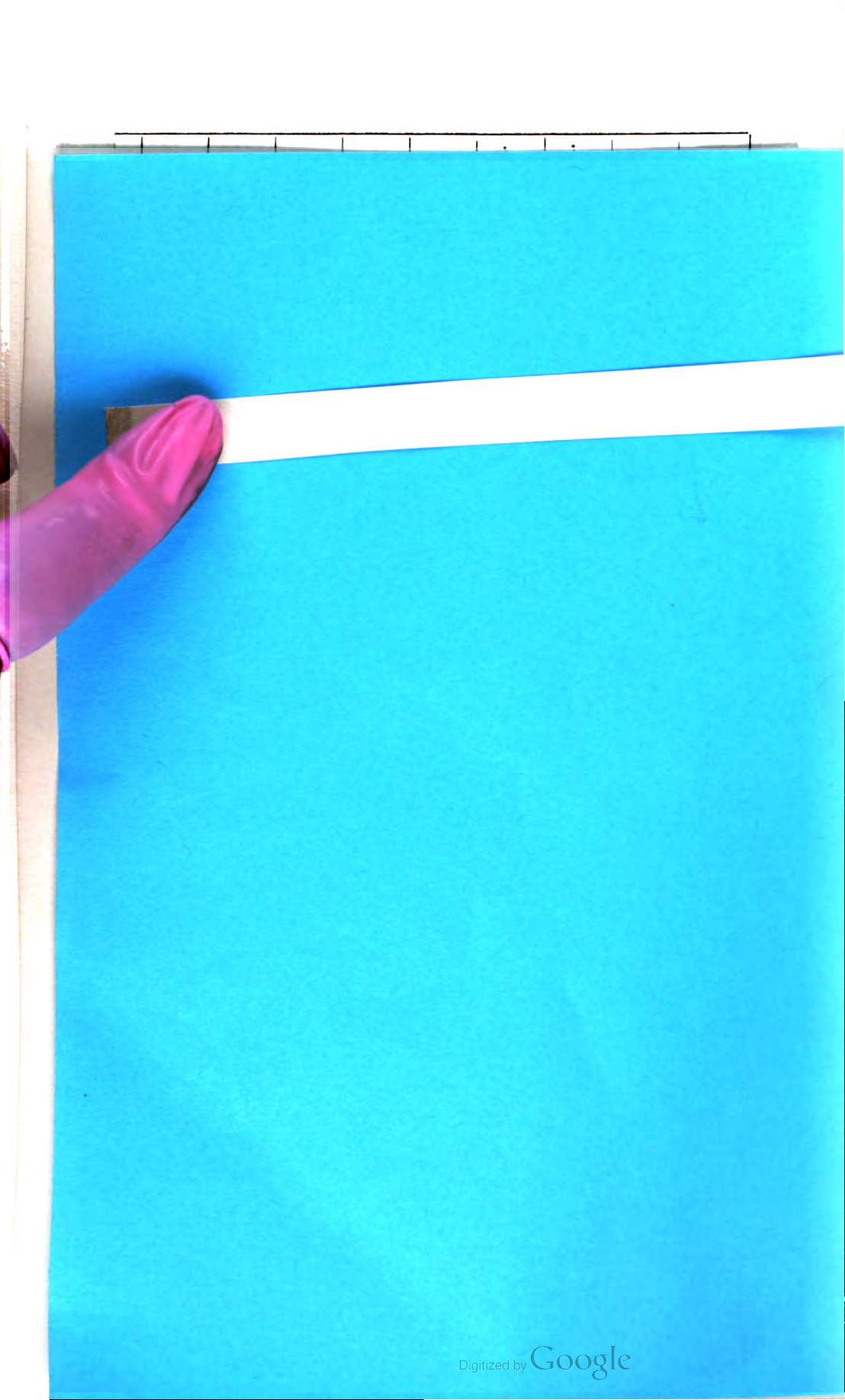
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CHAPTER XXIX.

MODERN QUICK-FIRING GUNS.

(I am indebted to the R.A. Journal for the use of many of the blocks illustrating this Chapter.—H.A.B.)

Weight of Gun and Carriage.

Two types of field-gun are in existence, a heavy and a light one. In both types the total weight of gun limbered up, with detachment, is kept within the power of a six-horse team. The proper load for such a team is variously estimated at from 40 to 45 cwt. But in the heavy type of gun the available weight is utilized in providing a gun of maximum power, with a small and light limber carrying comparatively few rounds; while in the light type the weight on the limber wheels is approximately equal to that on the gun wheels, and some 40 rounds of ammunition are carried.

The theory of the matter is as follows:—The advocates of the heavy and powerful gun hold that a Q.F. field-gun, to be of any use, must have a large supply of ammunition close at hand. That is to say that in action the gun must have a wagon holding say 100 rounds either close behind it or alongside it. Therefore the gun must *always* be accompanied by a wagon. This being so, the weight of the gun may be increased proportionally to the increased number of men available to handle it, namely, the men carried on the gun and the men carried on the wagon. If a detachment of five men can handle a gun weighing 18½ cwt., then seven men should be able to handle a gun of $\frac{7}{5} \times 18.5 = 25.9$ cwt., with equal ease.

On the other hand, the advocates of the lighter type hold that a gun which is dependent for efficiency upon the constant presence of its wagon is not wholly serviceable, and further that the unequal distribution of the weights upon gun wheels and limber wheels makes the draught considerably heavier.

The latter objection can be got over by carrying 3 gunners on the limber and none on the axletree seats, which are either abolished or left spare for emergencies. Opinions differ as to the best distribution of weight between the gun and limber wheels; but it is agreed that with the detachment mounted the weight on the limber wheels should not exceed the weight on the gun wheels. Most authorities hold that for ease of draught the load on the leading wheels should be somewhat less than that on the following wheels.

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MUZZLE ENERGY.

The proportion of muzzle energy to weight of gun and carriage varies considerably, as is shewn by the following table:—

	Weight of gun in action. cwts.	Muzzle energy foot tons.
France (1902)	22.25	333
Russia (1903)	22.5	380
Switzerland (Krupp, 1903) ...	19.75	245
America (Ehrhardt, 1903).....	20.75	300
England (1904)	23.75	337
Spain (Schneider, 1905)	21.25	267

It will be noted that the Russian gun is far more powerful in proportion to its weight than the rest. Of the remainder, the French gun easily surpasses the others. Even allowing for a saving of 1 cwt. by the use of the compressed air gear, which is not free from defects, the figures shew that other nations have still something to learn from the French designers.

WEIGHT OF SHELL.

There is a further division of opinion among the advocates of the heavy powerful gun as to the weight of the shell.

A gun of given weight can fire either a light shell with a high velocity or a heavy shell with a lower velocity. The former has the advantage of a flat trajectory, tending to neutralise the errors in ranging and fuzing which must necessarily occur on service; the latter contains a larger number of bullets per shell. Since however the number of light shell which can be carried is proportionately greater than that of the heavier shell, the high velocity gun can put the same number of shrapnel bullets—and those more effective, owing to the flatter trajectory—on the target as the low velocity gun. But it will take a larger number of rounds, that is, more time, to do so.

Thus we see that the advantage of the heavy shell lies in *concentration of effect*. It is this undoubted advantage which has secured the adoption of the magazine rifle, which does not really fire any faster than the single-loader, but is capable of developing an intense fire-effect for a short period.

Whether in the case of the field-gun this advantage counterbalances that of the flat trajectory is still an open question.

Two other arguments are urged in favour of the light shell. First that since a large number of shell must be wasted in ranging, it is better to waste light shell than heavy ones. And second, that the most important duty of artillery is to attack shielded guns by making direct hits on them with high-explosive shell. Now a small H.E. shell, if it hits a gun, will disable the detachment as effectively as a large one, and the probability of hitting increases with the number of rounds fired. Therefore in this nature of fire the gun firing a large number of light shell has the advantage of the gun firing a lesser number of heavy ones.

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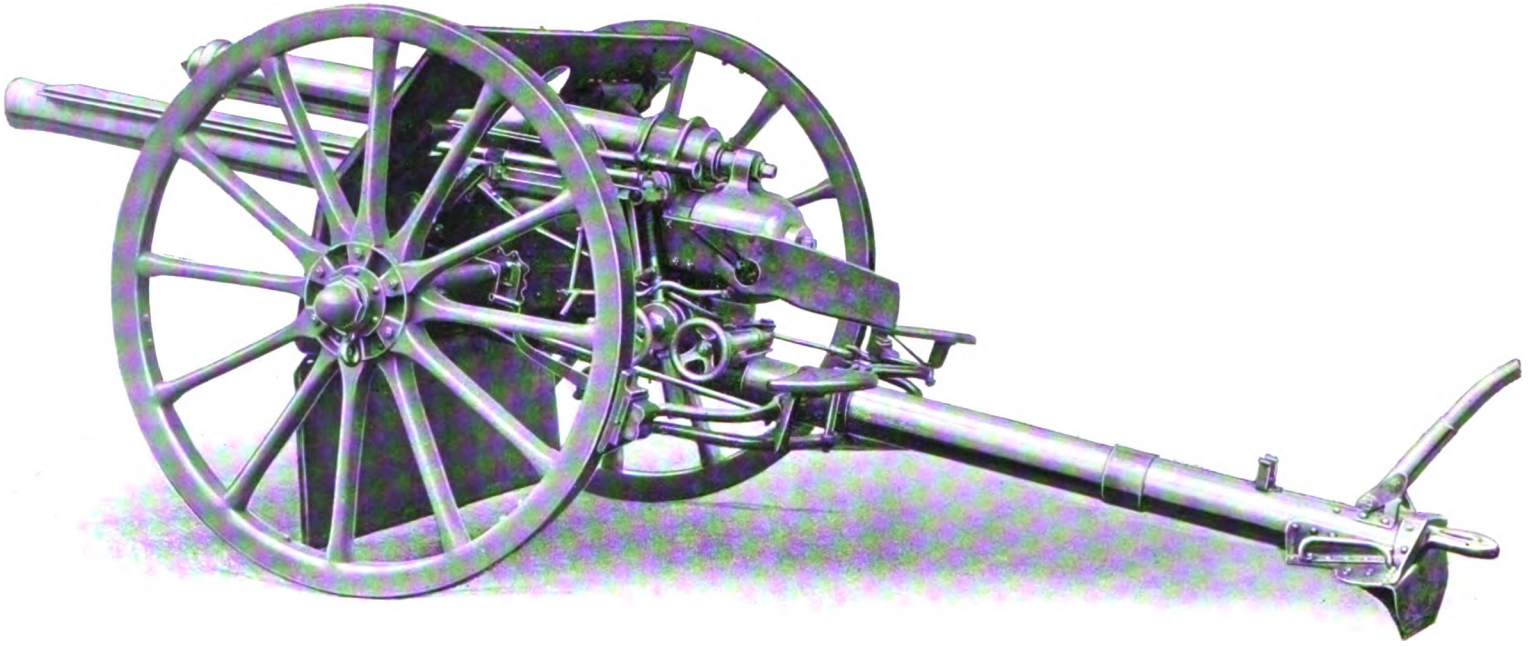

FIG. 90.

18-PR. Q. F. GUN.

1903.

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So difficult is it to estimate the relative values of these conflicting considerations, that we find the three typical *heavy* field-guns which have so far been produced differing widely in ballistics. The French field gun, which was first in the field, fires a 15.88 lb. shell with M.V. of 1740 fs. The English gun fires an 18.5 lb. shell, M.V. 1610 fs.; and the Russian gun a 14.71 lb. shell, M.V. 1930 fs.

Where artillery scientists differ so widely, who is to decide? Volumes might be written in support of any one of the three last-mentioned types. The question is rendered more difficult by the fact that most of the nations now re-arming have adopted a different nature of gun altogether—namely a light field gun, weighing not more than one ton unlimbered, and of only moderate power. Thus Austria, Italy, Switzerland, Norway, Sweden, Denmark, Spain and Portugal—to say nothing of smaller states such as Roumania and Mexico—have all selected guns firing shell of from 6 to 6.5 kilos. (13.2 to 14.3 lbs.) with a velocity of about 500 metres, or 1640 fs.

THE 1903 ENGLISH Q.F. HORSE AND FIELD EQUIPMENT.

The 18 pr. Q.F. Gun.

This gun is illustrated in Figs. 90 and 91.

The Gun.

The gun is a wire-wound nickel-steel gun of 3.3 inches calibre. It has two guide-ribs extending for nearly its whole length. It recoils in a bronze cradle pivoted on the lower carriage. The cradle trunnions are set at an angle to the horizontal to compensate for the mean angle of drift.

Recoil is checked by a hydraulic buffer placed above the gun, surrounded by a set of telescopic running-up springs. (See page 41.)

The Breech Action.

This is of the cylindrical single-motion screw type described on page 11. On pulling the breech lever from left to right the effect is first to turn the breech screw through a quarter of a circle and then to withdraw it, the screw and carrier swinging round to the right. As the carrier swings a cam on the hinge-pin engages the outer end of the extractor, which projects outside the breech; it first prises the cartridge case out of its seat, and then, with a sharper movement, ejects it to the rear.

The Firing Gear.

This is a repeating trip-lock. The striker is central, and rebounds within the face of the breech-screw after striking the cap. It is actuated by a tripper projecting from the left-hand side of the breech of the gun. When the breech is closed the tripper enters a recess in the face of the carrier. This tripper is connected to a firing-lever placed conveniently to the layer's right hand. When the lever is pulled the tripper first draws back the striker, compressing the main-spring, and then releases it.

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The Elevating Gear.

A long elevating screw is set on the left-hand side of the trail. The lower end passes through a nut on the trail, the upper end through a nut on the cradle.

The Sighting Gear.

The gun has the independent line of sight (see pages 22 and 23). The sight is a rocking-bar pivoted on the left cradle trunnion, carrying a telescope and open sight. It is capable of traversing for deflection. The rear end of the bar is connected to a pivot in the centre of the elevating screw. When the lower nut through which the elevating screw passes is turned by the laying wheel, the gun, the screw, and the sight go up or down together; when the upper nut is turned by the elevating wheel the gun goes up or down the screw without moving the sights. The angular movement of the gun with respect to the sight-bar is recorded on an indicator drum at the right-hand side of the cradle. To alter the elevation say from 4000 to 4300 yards the elevating number merely turns the elevating wheel till the indicator points to 4300, without disturbing the laying.

For laying on an auxiliary mark an all-round laying plane is fitted. This is a horizontal graduated circular plate fixed to the top of the shield, with a straight-edge and open sights. The graduations are similar to those on the battery telescope stand.

The clinometer is of the arc type, described on page 24.

Traversing Gear.

The gun and cradle are mounted on a small top carriage. This has circular flanges at bottom and traverses on a circular traversing-bed fixed to the axletree.

The top carriage is traversed by an endless screw engaging with its rear flange.

The Clamping Gear.

For travelling, the gun is clamped to the trail by an eccentric jamming clutch so that there is no strain upon the elevating gear.

The Trail.

This is a straight steel tube secured under the axletree by steel loops. At the rear end is a fixed spade similar to that on the 15 pr. Q.F. gun.

The Axletree.

This is a hollow steel forging, square in the centre.

The Wheels.

These are of the double-strutted pattern with 14 spokes, 4′ 8″ in diameter. There is a cap to keep dust out of the pipe-box.

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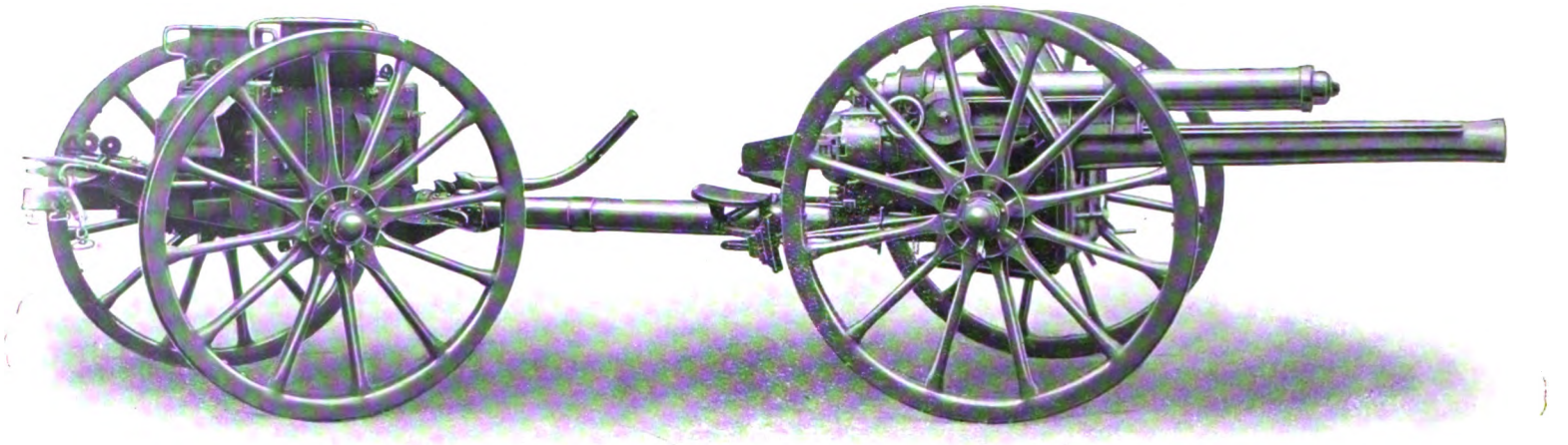

FIG. 91.

18-PR. Q. F. GUN.

1903.

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The Brake.

This consists of two arms carrying brake-blocks. The arms are hinged on the trail and are connected by tension-rods and bell-crank levers to a cross connecting-piece in front, so that if one tension-rod is shortened by a screw and hand-wheel both brake-blocks are pulled against the wheel. There is an eccentric link in the left tension-rod which allows the brake to be thrown out of gear if it is desired to shift the gun in action.

The Shield.

This is of hard steel plate and is bullet-proof up to very short ranges. The upper portion is curved backwards to give additional protection. The lower portion is hinged for travelling.

THE LIMBER.

This is a steel box limber very similar to the E.O.C. limber illustrated in the next chapter, but without the high guard-irons. It is divided into nine horizontal compartments; the central one contains tools and spare parts, and each of the others contains three basket-work tubes each holding a round of fixed ammunition. The door opens to the rear and hangs down to the ground, forming a shield for men working behind it.

THE WAGON BODY.

This consists practically of two limbers, the rear one having a perch instead of a pole. Each carries 38 rounds. The wagon, limbered up, is placed beside the gun in action, and the ammunition is handed straight from the wagon to the loading number. On top of the rear box is set the range dial, which is similar to the range drum on the gun. Within the range dial is the fuze dial, which can be shifted with reference to the former so as to alter the fuze graduation which appears opposite to any range on the dial.

Thus the battery commander does not have to concern himself about the length of fuze, but simply orders "Corrector (say) 50," the fuze dials are set accordingly, and the fuzes set at the graduation which now appears opposite to the range ordered.

AMMUNITION.

Fixed ammunition is used; it is always carried fuzed, and is similar in appearance to Fig. 41, opposite to page 63. Shrapnel only is carried. The fuze is on the same principle as that shewn on page 69.

THE 13 PR. Q.F. GUN.

No separate description of this is required; the construction is similar throughout to that of the 18 pr. Details of weights, &c., are given in the Table.

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PERFORMANCE OF THE NEW EQUIPMENT.

The new guns are particularly steady on firing and can be fired at the rate of 20 rounds (aimed) per minute. They are remarkably accurate, being much superior to the 15 pr. Q.F., which is considered a good-shooting gun. The powerful 18 pr. shrapnel gives good distribution of bullets over a depth of 300 yards at medium ranges, and is effective up to 6500 yards. The sighting arrangements are excellent and the independent line of sight enables the ranging to be conducted far more quickly than with the old materiel. Altogether the new guns may be considered at least equal to those of any foreign power.

DETAILS OF 13-PR. AND 18-PR. EQUIPMENTS.

PARTICULARS.	13-PR.	18-PR.
Muzzle Velocity	1,658 f.s.	1,610 f.s.
Calibre	3″	3·3″
Weight	6 cwt.	9 cwt.
Breech Mechanism	Swinging block	Swinging block
Rifling { Grooves, Number	18	18
Rifling { Twist	Uniform	Uniform
Firing Mechanism	Percussion	Percussion.
Approximate weight of gun and carriage	Cwt. qr. lb. 18 0 12	Cwt. qr. lb. 23 3 3
Approximate weight of carriage limber	12 0 0	14 3 3
Approximate weight behind traces	30 0 12	38 2 6
No. of rounds in carriage limber	24	24
	Cwt. qr. lb.	Cwt. qr. lb.
Approximate weight of wagon (filled)	15 1 21	19 1 14
Approximate weight of wagon limber (filled)	14 1 27	18 1 16
Approximate weight behind traces	29 3 20	37 3 2
No. of rounds in wagon limber	38	38
No. of rounds in wagon	38	38
Height of axis of gun from ground	3′ .86″	3′ .86″
Wheels { Track	5′ 2″	5′ 2″
Wheels { Height	4′ 8″	4′ 8″
Weight of projectile (filled & fuzed)	12½ lb.	18½ lb.
Ammunition	Fixed and fitted with percussion primer.	Fixed and fitted with percussion primer.

War Office (A2),
6th February, 1905.

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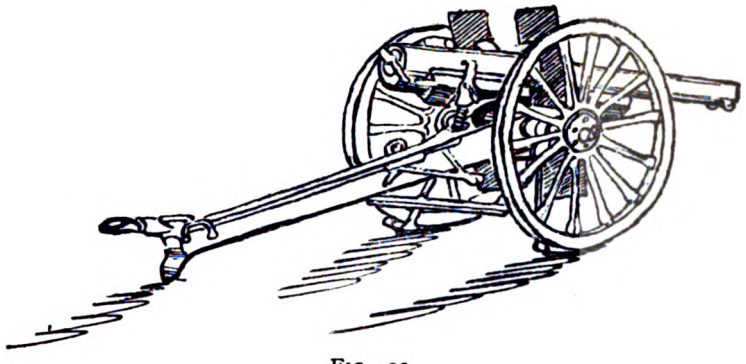

FIG. 92.

THE FRENCH 1899 Q.F. EQUIPMENT.

This was the pioneer of all modern Q.F. equipments, and still maintains its superiority in many respects over later designs.

It is a high-velocity 16-pr. of approximately the same power as our 18-pr. Q.F. gun.

The gun recoils on its carriage for a distance of 43 inches. The recoil is checked by a hydraulic buffer, and the gun is returned to the firing position by a piston actuated by compressed air at a pressure of 177 lbs. to the square inch. The carriage is perfectly steady during firing, and is held by a narrow pointed spade and by tire brakes which are dropped under the wheels so as to form drag-shoes. These brake-blocks have fins on the ground surface to prevent lateral movement. The breech is closed by a Nordenfeldt eccentric screw.

The small projections seen below the muzzle in the figure fit under the cradle guides, and so support the gun in the extreme position of recoil.

To traverse the gun, the gun and trail together are shifted laterally along the axletree by worm gearing.

In order to bring the gun into action, or to shift on to a fresh target, the trail has to be raised shoulder high to allow the brake-blocks to drop under the wheels; the trail is then dropped so as to bring the gun into the line of fire. This operation is called *abatage*. In other Q.F. guns the spade can be shifted laterally before the first round has been fired; but with the French gun the spade, once dropped, cannot be shifted. If, therefore, the gun is not pointing within 3 degrees of the target (the limit of the traversing gear) the operation of *abatage* has to be repeated. This undoubted disadvantage has led most other nations to choose guns with pivoted cradles or pivoted intermediate carriages in preference to those on the axle-traversing system.

The gun has the independent line of sight, the pedestal sight being supported by a radius bar pivoted on the same horizontal axis as the cradle. The elevating screw is stepped on the rear end of the bar, and a toothed arc attached to the bar actuates the range dial on the cradle, which thus always marks the true elevation above the line of

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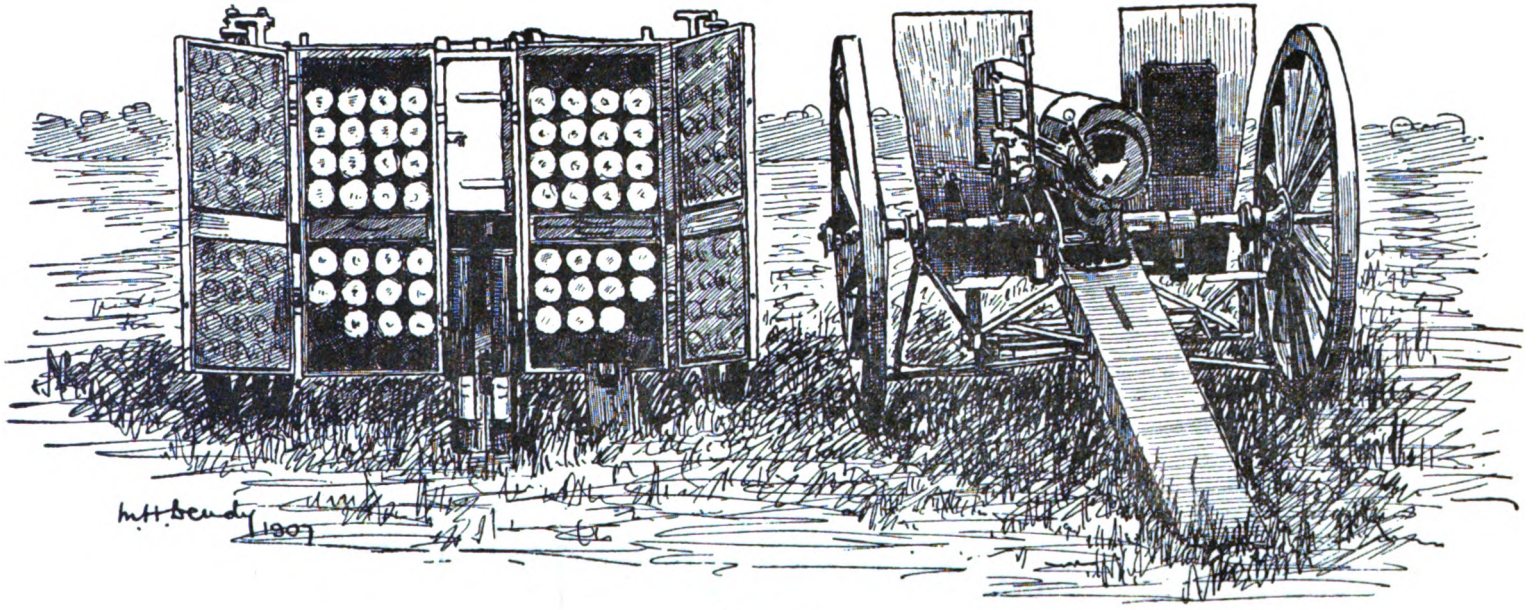

FIG. 93.

THE FRENCH Q.F. FIELD GUN.

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Page 219.—The new German gun is officially styled C/96 N.A. (*neuer Art.*). The 1896 gun had a folding, not a spring spade. The German field artillery is now organized in regiments, each regiment consisting of two divisions, each division of three batteries and a light ammunition column. Each battery has 6 guns and 6 wagons, and the light A.C. has 21 wagons, besides baggage and stores. A wagon body is unlimbered (not tipped) beside each gun. 5 gunners are carried on the gun and 5 on the wagon.

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sight. There is no foresight, and the pedestal sight is used principally for direction, elevation being given by clinometer in metres of range.

In 1902 a shield was added, calculated to keep out infantry bullets at 400 yards. To compensate for the increased weight the axletree seats were removed, 3 gunners being carried on the gun-limber and 3 on the wagon-limber.

The French gun is specially designed to give a far-reaching zone of shrapnel effect, which is required by the French system of fire-tactics. (See Chapter XXVIII.) It has therefore a flat trajectory, due to a high muzzle velocity and to a shell with high ballistic co-efficient. The shrapnel bullets (38 to the pound) are heavier than those used by any other nation except Switzerland.

Ballistics.

General Rohne gives the following figures. It will be found interesting to compare them with the values as determined by Table X., Text Book of Gunnery.

Range, metres.	Elevation.	Angle of descent.	Remaining velocity. fs.
1000	1° 11′	1° 22′	1371
2000	2° 49′	3° 45′	1112
3000	4° 7′	6° 7′	1004
4000	7° 45′	11° 38′	900
5000	11° 7′	16° 41′	820
6000	15° 15′	22° 30′	768

The principal details are given in the Table of Field Guns. The following additional details have been published:—

Total length of gun	8 ft. 10½ in.
Height of axis	3 ft. 6 in.
Weight of carriage	15½ cwt.
Weight of limber without equipment... ...	14 cwt.
No. of rounds in wagon limber	24
No. of rounds in wagon body	72
Rate of fire per minute, about	15 rounds.
Height of shield	4 ft. 6 in.
Colour	Grey.

THE GERMAN 1905 Q.F. EQUIPMENT.

(Reprinted by permission from the R.A. Journal.)

The German 1896 gun was a 15-pr. with spring spade, almost exactly equal in power to our 15-pr. B.L. gun.

In the new equipment the old gun and ammunition have been retained, and the gun has been mounted on a gun-recoil shielded carriage.

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The Gun.

This has been altered by removing the vertical trunnion, shrinking on two chase-rings with guide pieces to slide on the cradle guides,

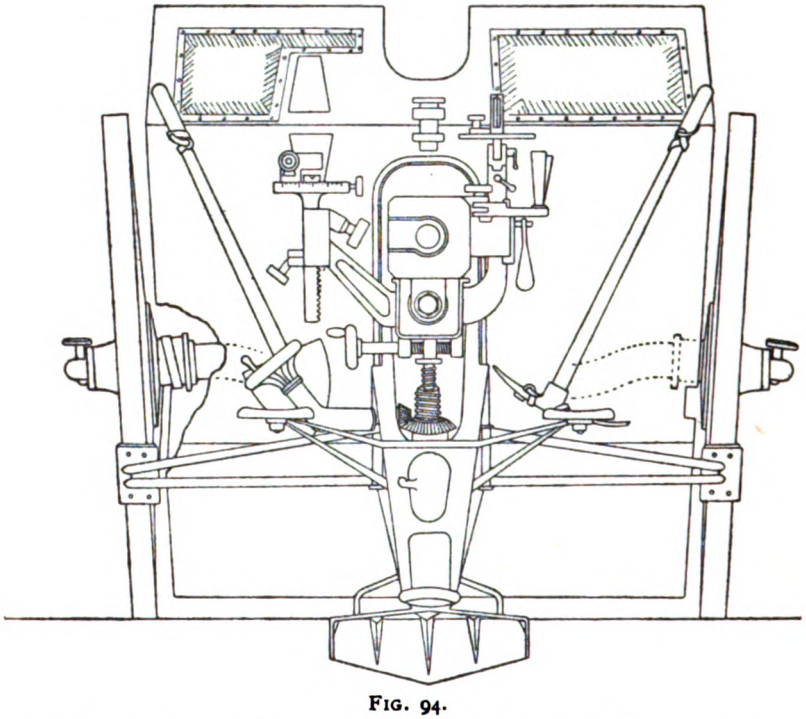
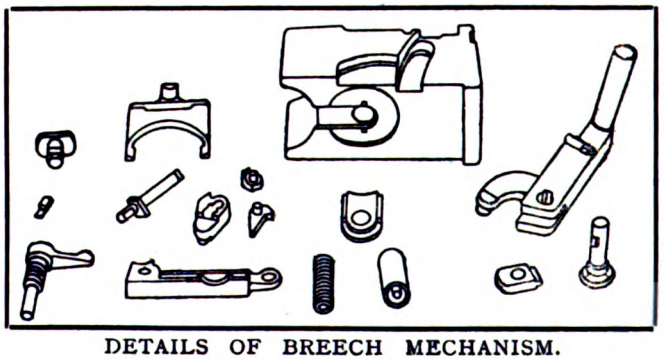


FIG. 94.

and adding a horn to connect the gun with the buffer. It is said that the gun has been turned down to reduce the weight, but this is doubtful. The gun is rifled with a twist increasing from 1 in 50 to 1 in 25 near the muzzle.

The Breech Action.

This is the Ehrhardt single-motion wedge, as shewn in the figures. The action has been slightly modified and is now known as the Spandau wedge.



DETAILS OF BREECH MECHANISM.

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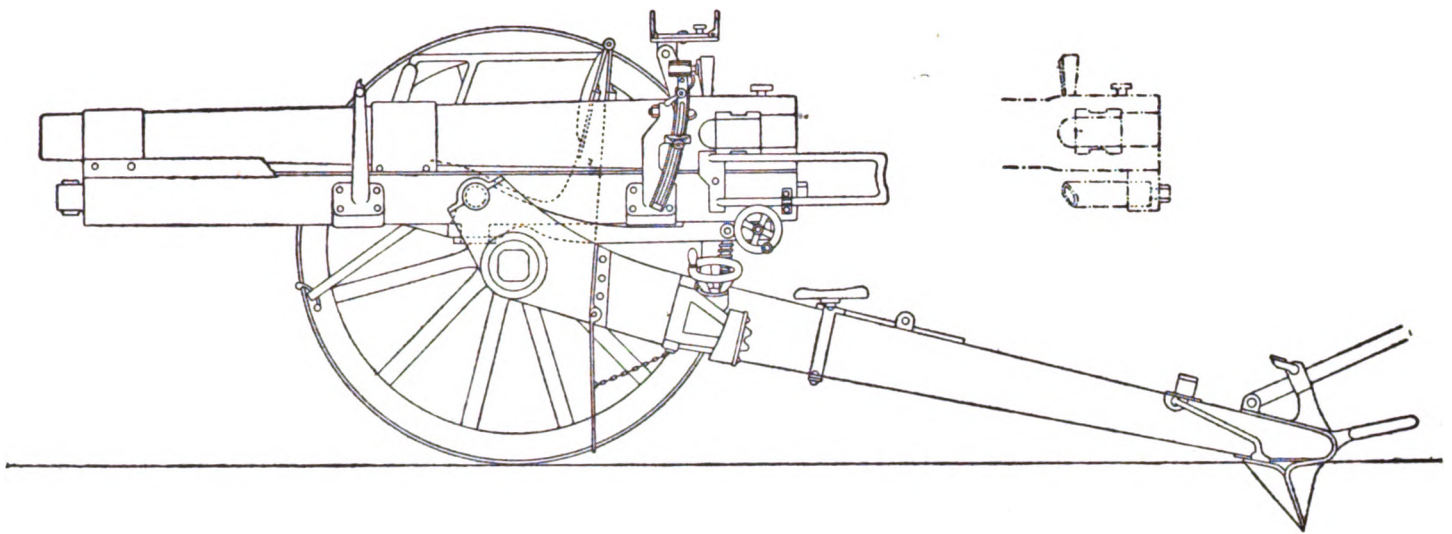

FIG. 95.

THE GERMAN Q.F. GUN.

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The Firing Gear.

In the photos from which the figures are taken, the gun is shewn as being loaded and fired from the right-hand side. A short padded pull is attached to the trigger of the repeating trip-lock; this is pulled out of the firing number's hand when the gun recoils. The method of firing from the right-hand side is that laid down in the German drill-book. But the Ehrhardt action can also be fitted with a firing lever on the left-hand side, and it is possible that this modification may be introduced.

The Sights.

The gun has three sights and a clinometer.

(a). Ordinary open sights of the arc type, with an inner bar which draws out to make the fuze agree with the gun elevation.

(b). On top of the arc sight is fitted a single-barrelled *Z*eiss prismatic telescope, set with the tubes side by side. This telescope has cross lines and gives a so-called optical line of sight, independently of the foresight.

(c). The laying plane is on the right of the gun, and consists of a graduated circle with sight-vanes and clamp. It is mounted on a standard which (presumably) can be drawn out till the line of sight clears the top of the shield. This laying-plane cannot be cross-levelled, and is used for laying for direction only.

The gun has not the independent line of sight.

(d). The clinometer is of the arc type and is set on the bar of the arc sight, low down. The elevation given by it is read on the arc sight. The graduations on the face of the clinometer itself are for setting the angle of sight.

The Recoil Gear.

The detail of the buffer is taken from a drawing of the Krupp 1905 buffer. It shows no check buffer, but a Vavasseur valve between the two portions of the divided piston to regulate the resistance in running-up. But it is not known whether this part of the Krupp gear has been adopted.

The recoil is said to be 44 inches; this compresses the single column of running-up springs to only about half of their working length.

The Cradle.

This is a steel trough closed by a top plate, the upper edges forming guides for the gun. It pivots on a vertical trunnion in the saddle.

The Saddle.

This pivots on horizontal trunnions in the trail brackets. It is prolonged in rear to form the traversing bed, which is supported on the elevating screw.

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The Elevating Screw.

This is of the ordinary double-screw pattern. The spindle is prolonged so as to bring the elevating wheel in front of the layer's seat,

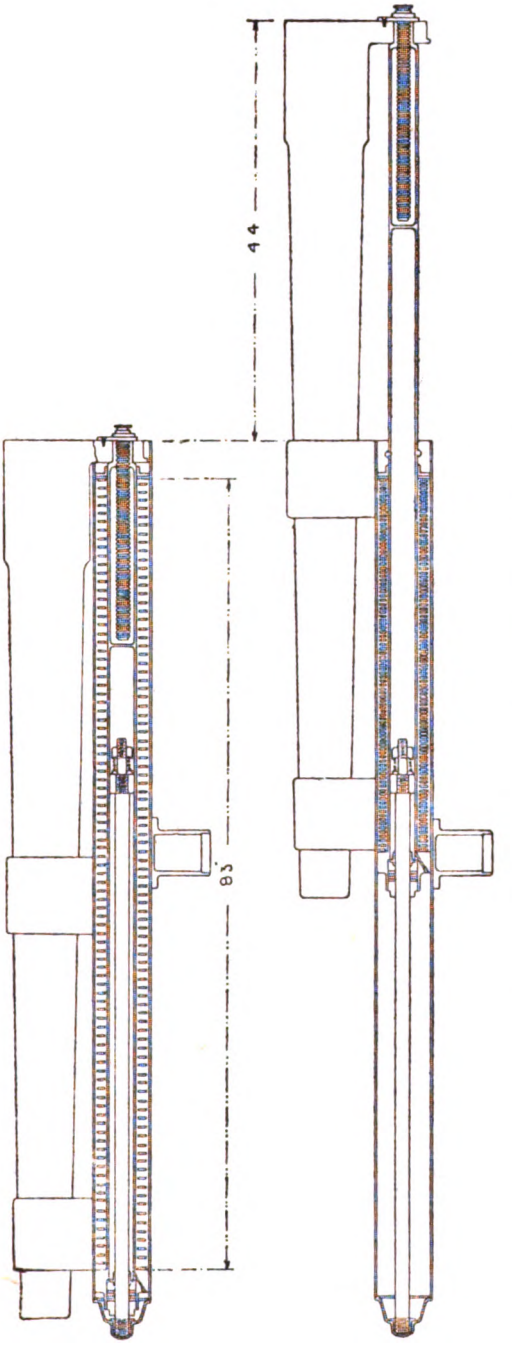

FIG. 96. DETAIL OF KRUPP BUFFER AND SPRINGS.

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so that he can use both hands to it. This seems to indicate a heavy preponderance.

Traversing Gear.

This is of simple pattern as seen in the figure. There is apparently no clamping gear for travelling.

The Trail.

This is a plain box trail, partly open on top to allow of 16½° elevation being given. It is slightly bent to give room for the elevating gear. The clearance under lowest point when limbered up is about 18 inches. The trail appears to be about 8′ 4″ long on the ground line. With the low muzzle energy (241.7 foot-tons) and 44-inch recoil, this gives a large excess of stability, and the carriage is perfectly steady in firing.

The Axletree.

No details available. It appears to be cranked downwards about 2 inches to keep the axis of the piece low. The height of axis is approximately 40 inches.

The Wheels.

These are the same as in the old equipment, namely 12-spoke wooden wheels, single strut, without spoke-shoes.

Brakes.

These are used for travelling only, and are applied from the off axletree seat. A flat braided wire rope, faced with leather, is attached to the brake-arm close to the brake-block. The rope takes one turn round a drum on the inner flange of the nave. When the loose end of the rope is tightened by a lever alongside the axletree seat the wire rope grips on the drum and the wheel as it revolves pulls the brake-block hard against the tire.

The Shield.

This is in three pieces, hinged horizontally, as shewn. It is set far back behind the axletree, partly for additional protection, partly to give room for the axletree seats, The height with top flap raised is 5 ft. 6 inches, and the area about 23 square feet.

The latest accounts state that the shield is 4 mm. or 0.1584 inch thick. This gives a weight of about 154 lbs.

Ammunition.

This is at present unchanged. It consists of shrapnel and H.E. shell, the latter filled with nitro powder. Both are fuzed with a T. and P. fuze which burns up to 5,000 metres. The cartridge consists of 1.25 lbs. of tubular nitro powder in a separate brass case. Four rounds of ammunition are packed in a basket, but in the new wagons to be added only two, or possibly three, rounds will be contained in each basket.

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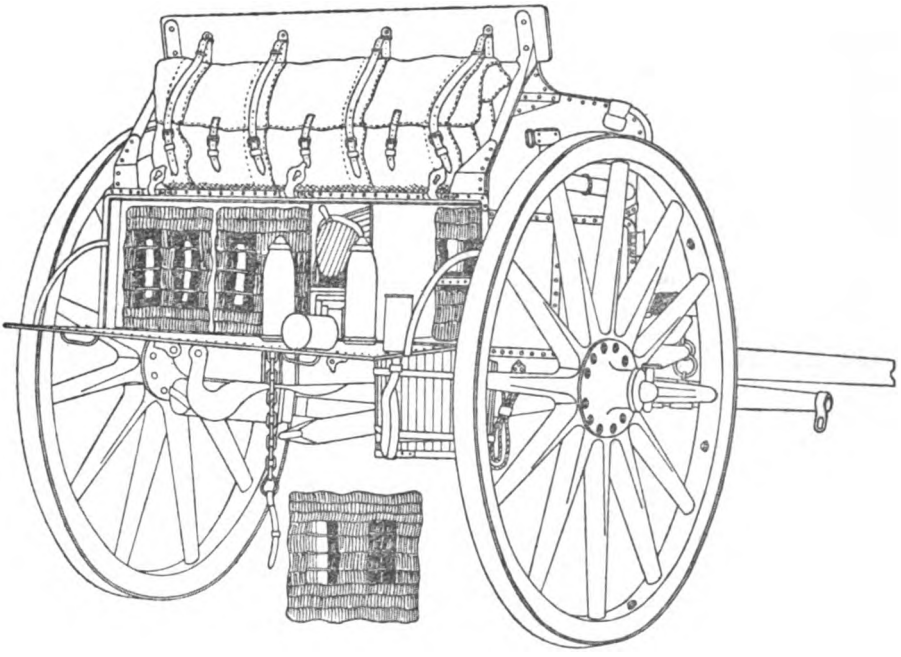
The German authorities are experimenting with an *Einheitsgeschoss* or universal projectile which is to replace both shrapnel and H.E. shell. It is on the lines of the high-explosive shrapnel described in Chapter IX.

Limber.

This is unchanged. It is seated for three gunners.



THE LIMBER.

Wagon.

It is stated that the present wagon body is to be fitted with shields in rear similar to those of our 18-pr. equipment. The wagon body will not be detached, but the wagon and limber will be unhooked beside the gun.

Composition of Battery.

The battery consists of six guns. At present there are only six wagons, of which three are with the guns in action. But it is stated in the German Press that in future one wagon will be beside each gun in action. The detachment will then be carried as follows:—

No. 1 on horse.

Nos. 2, 3 and 4 on gun limber.

Nos. 5 and 6 on wagon limber.

No. 7 on wagon body.

At the present time 5 numbers are carried on the gun and 2 on the wagon.

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The present light ammunition column consist of twelve wagons each with 88 shrapnel, and nine wagons each with 88 H.E. shell. There is one such ammunition column to every six batteries. It has now been decided to add 3 wagons for each battery, an addition of 18 wagons, making 39 wagons in all with the light column.

Weight.

The weight in action of the new equipment is not given, but by comparison with Krupp models it should be about 21 cwt. with 4 mm. shield.

German accounts give the weight in action as 18.5 cwt., weight limbered up without equipment 34 cwt., weight of wagon without shield 34.9 cwt. But these figures are doubtful. It is also stated by one writer that the gun itself has been turned down so as to reduce its weight to 7.65 cwt.

The weight in action of 18.5 cwt. given by the German Press cannot be accepted without confirmation. For Krupp builds field-guns to the same factor of strength and serviceability as the Government. And if he cannot get an original design under 1 ton in action, it can hardly be supposed that the German Government can do better with a converted gun.

Ballistics.

M.V. 1525 fs., shell 15 lbs.

Range, metres.	Elevation.	Angle of descent.	Remaining velocity, f.s.
1000	1° 39′	1° 49′	1210
2000	3° 38′	4° 45′	1071
3000	6° 15′	8° 41′	915
4000	9° 30′	13° 30′	840
5000	13° 21′	19° 21′	778
6000	18° 11′	26° 30′	721

These are the ballistics given by General Rohne for the German gun. But it seems probable that the General has rather over-estimated the performance of the gun, and the remaining velocities appear to be at least 10% in excess of their theoretical value.

The principal details are given in the Table.

THE RUSSIAN 1900 Q.F. EQUIPMENT.

(See Fig. 97.)

This was designed by General Engelhardt, and manufactured at Putiloff, Russia, in 1900.

This gun had a very high muzzle velocity, believed to be 1930 fs., and a shell of 14.71 lbs. The head of the shell was struck with an exceptionally long radius, namely 2.75 diameters. The gun fired fixed ammunition.

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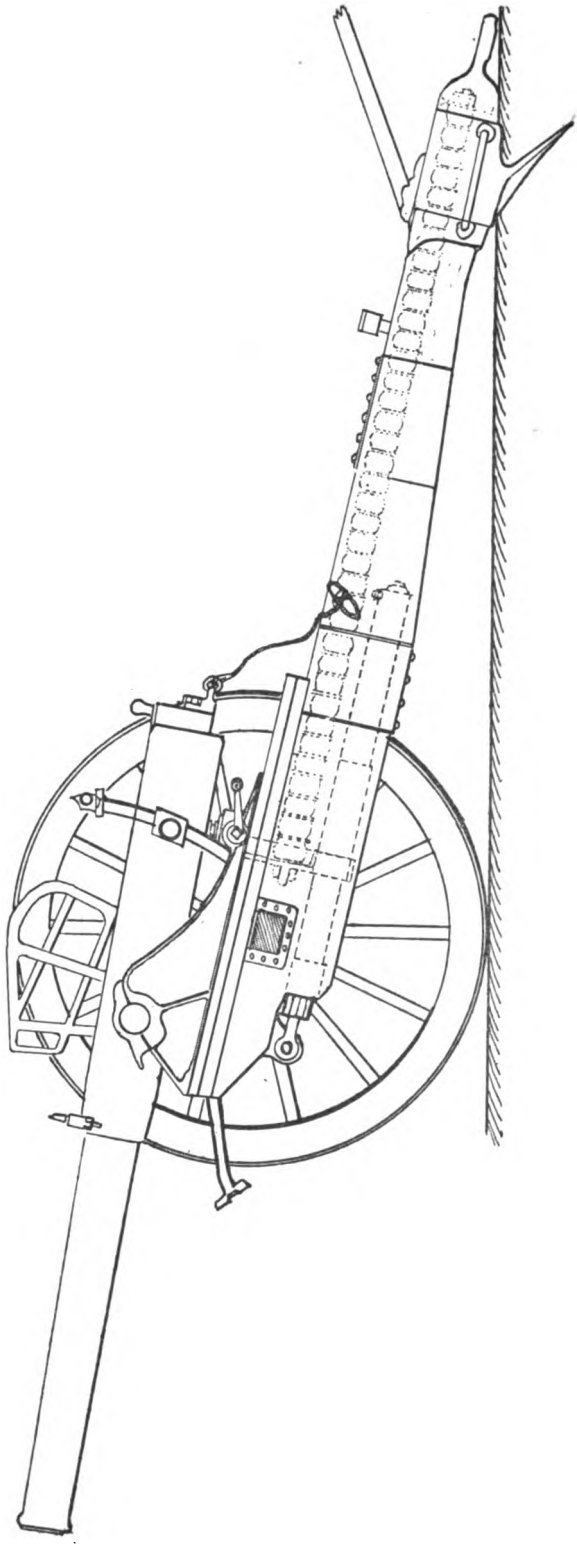

FIG. 97. THE RUSSIAN 1900 FIELD GUN.

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The Russian 1900 gun had no shield, the whole of the available weight being utilized in power. The arrangements for checking recoil were peculiar. The gun was mounted on a pedestal, which was arranged to ride upon the trail, and to slide down the trail in recoiling. The length of recoil was 3 feet. The trail was tubular, with a longitudinal slit in the upper surface. The buffer-cylinder was inside the trail, and the trail also contained the running-up springs, which were discs of india-rubber threaded on a spindle and separated by washers. The carriage was anchored by a spade and tire brakes. The breech action was a cylindrical interrupted screw, Schneider type, single motion. The sights were on the gun and recoiled with it.

The gun could be fired with the brake-cylinder empty, but was then unsteady.

The fuze was of aluminium, of the double-banked pattern, weighing 9½ oz. It burnt 22 seconds.

The wagon in action was placed beside the gun.

The details, so far as known, were as under. (Authority Revue d'Artillerie, October, 1903, and various German publications.)

Calibre, 76.2 mm., or	3 inches
Length of gun, about	9 feet
Weight of gun, 393 kilo., or	7¾ cwt.
Height of axis, about	3 ft. 6 in.
Length of trail, about	9 feet
Height of wheels	4 feet (?)
Weight of carriage	14½ cwt.
Weight of gun in action	22¼ cwt.
Weight of limber with equipment	15 cwt.
No. of rounds in limber	36
Weight of gun & limber packed, without gunners	37¼ cwt.
Weight of shrapnel or H.E. shell	14.71 lbs.
No. of bullets	260
Weight of bullets	43 to the lb.
Muzzle velocity	1930 fs.
Muzzle energy	380 foot-tons
Maximum pressure in bore	14.77 tons
Remaining velocity at 2335 yards	1118 fs.
Rate of fire, rounds per minute, maximum ...	15

THE 1902-03 RUSSIAN Q.F. EQUIPMENT.

(Reprinted, by permission, from the R.A. Journal.)

The 1900 pattern Q.F. gun, used in the Russo-Japanese War, was a very powerful weapon, and its shooting gave great satisfaction. The equipment was however open to the following objections:—

(*a*) The gun was unsteady, requiring re-laying after every round.

(*b*) The sights recoiled with the gun.

(*c*) The indiarubber running-up springs gave trouble.

(*d*) The gun was too heavy for the country.

(*e*) It had no shield.

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It was accordingly determined to bring out a fresh design, preserving the high ballistics of the old gun (1930 fs. with a shell weighing 14.71 lbs.) and free from the objections to which the older gun was liable. This gun was known as the 1902 pattern.

In 1903 this equipment was again modified by removing the axletree seats and adding a shield and a panorama sight.

No drawings of the 1903 equipment are yet available, but it is identical, except as regards the above modifications, with the 1902 pattern, a description of which has now been published by Captain Alexandrovitch of the Russian Staff.

The accompanying plate represents the 1902 gun. (Fig. 98.)

The Gun.

The gun is of nickel steel, calibre 3″, 32 calibres long. It consists of an "A" tube and jacket, secured at its forward end, 56.4″ from the muzzle, by a locking ring. The guides, which are under the gun, are continuous, and are formed partly on the jacket, partly on a guide-piece, both ends of which are formed into rings shrunk on to the chase. The rear end of the breech-piece is extended downwards forming a horn into which the buffer-cylinder is fixed. The breech-action is a single-motion cylindrical interrupted screw, generally similar to that of our 18-pr. Q.F., actuated by a hand-lever on top. It is intended for fixed ammunition. The firing gear is a repeating trip lock of very simple design. By pulling the tripper straight to the rear with a lanyard the striker is first pulled back and then released. The forked extractor is actuated by the carrier, which strikes it at the end of its swing, as in our 15-pr. Q.F.

The Sights.

The arc sight is much the same as that on our 15-pr. Q.F.; the foresight is hooded. The clinometer level is attached to the left-hand side of the arc sight, low down.

The goniometric sight is a simple circular laying-plane which can be set on top of the arc sight. It has two sight-vanes and a separate deflection scale. It does not correct for difference of level of wheels. In the 1903 equipment this laying-plane has been replaced or supplemented by a Goerz panorama sight which can be fixed on top of the arc sight.

The Cradle.

This is a steel tube, carrying guides for the gun on its upper surface. It has no traversing movement, but is mounted on horizontal trunnions on the trail. Traversing is effected by shifting the whole trail right or left along the axle. The cradle contains the buffer and running-up springs.

The Buffer.

This is of novel construction. In ordinary buffers the graduated resistance to recoil is obtained by allowing the liquid to flow past the piston through channels or ports of varying depth formed in the inner surface of the buffer-cylinder. But in this equipment the piston is a close fit in the cylinder, and the liquid has to flow through holes in the hollow piston-rod formed just forward of the piston.

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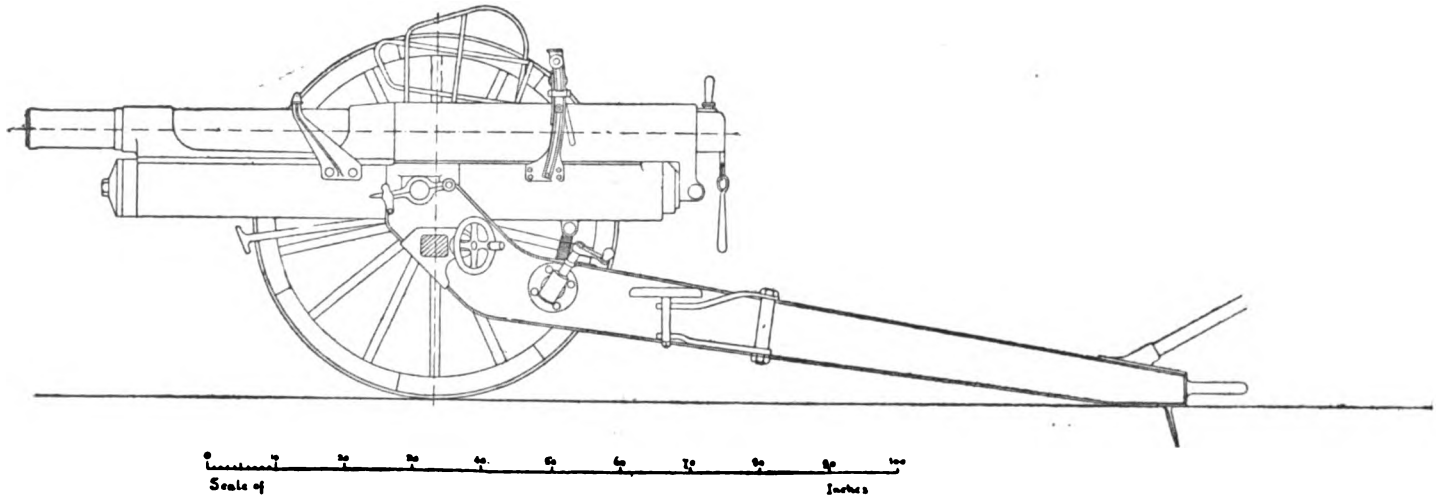

FIG. 98.

THE RUSSIAN 1902 Q.F. GUN.

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The hollow of the piston-rod is partly filled up by a tapered plunger fixed to the bottom, or rear end, of the cylinder.

The graduated resistance to recoil is obtained by varying the diameter of the plunger at different points, so as to alter the area of the annular channel through which the liquid has to flow. The buffer recoils with the gun; the piston rod is fixed to the cradle.

The action of the buffer is shown in the accompanying diagram. As the gun recoils, and the stability of the carriage decreases, the annular space at *a* increases in area, so that the resistance to recoil, and consequently the overturning pull on the carriage, is reduced.

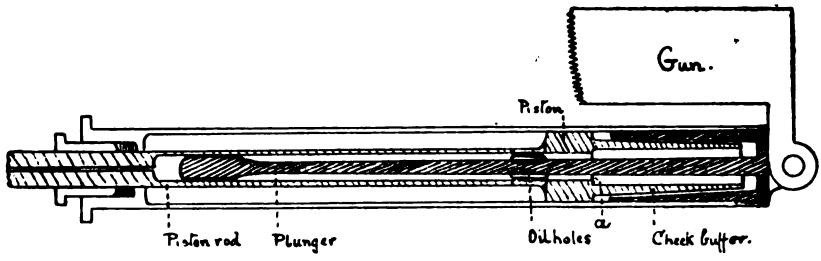

FIG. 99.

The Check Buffer.

To prevent the gun from running up too violently, the rear end of the piston is prolonged to form a check-buffer, which enters a bell-mouthed tube fixed to the bottom of the cylinder.

The buffer-liquid is light-gravity petroleum, which is said to alter but little in viscosity at low temperatures. The length of recoil allowed is one metre.

The Running-up Gear.

This consists of a single column of six helical springs of flat section. The springs are alternately right-handed and left-handed, and are separated by parting plates riding on the buffer. The spring column is 6′ 3″ long, and the springs are compressed on recoil into a space of 3 feet, or to rather less than half of their working length. The initial compression is about 5 cwt.

The Elevating Gear.

This is of peculiar design, and difficult to explain without a diagram. It consists of an inner screw hinged to the rear end of the cradle, an outer screw surrounding the inner screw, and a nut surrounding the outer screw. The nut is contained in a box pivoted between the trail brackets. The two screws are not, as usual, right and left-handed, but both right-handed. When the nut is turned the outer screw turns with it, since the friction between screw and nut is greater than between the two screws. The inner screw is screwed out as far as it will go, when the outer screw can turn no farther. As the nut continues to turn, the outer screw, now fixed, is then screwed out as far as it can go.

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Should it happen that the friction between the screws is greater than that between the outer screw and nut, then the outer screw is first screwed out as far as it will go, and then the inner one.

This arrangement has the advantage of enabling screws with coarser pitch and stouter threads to be used for the same ratio of gearing. It is not otherwise attractive.

The gear allows of about 17° elevation and 6° depression.

The Traversing Gear.

This is simply a transverse screw fixed at one end to a projection on the axle, and turning in a nut attached to the trail. It gives about 2¾ degrees of traverse each way.

The Trail.

This is a box trail about 9′ long on the ground line, of the Krupp bent pattern. It carries a large fixed spade, a folding handspike, and seats for the layer and breech-closing number on arms which fold forward alongside of the trail. The front end of the trail carries the cradle trunnion-holes above and the axletree bed below. The latter is lined with bronze and slides on the rectangular axletree.

The Axletree.

This is a solid steel forging, cranked 4″ downwards in the centre in order to allow the gun and cradle to be set as low as possible.

The Wheels.

These are of wood, with 7 felloes and 14 spokes, dished, with bronze naves. They are 4′ 5″ high.

Dragshoes.

There are no brakes on the wheels. Two dragshoes attached by chains to eyes 2′ 6″ from the trail eye are used both for firing and travelling.

Shield.

The exact dimensions are uncertain, but the shield will be in 3 parts, either 4½ mm. or 5 mm. thick, and about 5′ 6″ high. The axletree seats will be removed.

The weights and dimensions are given in the Table.

The following details have also been published:

Height of axis	33 inches
Trail lift	116 lbs.
Weight of smoke producer ...	1.34 oz.
Charge...	Tape nitro powder.

The Limber.

This contains 36 rounds packed by fours in magazines. The limber-hook, pole, and draught-loops are all set in indiarubber block springs.

The Ammunition.

The gun fires fixed ammunition. The 1900 gun fired shrapnel only, the 1902 gun was equipped with shrapnel and ring shell. The Russians are dissatisfied with the performance of the latter, and now propose to replace it by H.E. shell containing a nitro-powder burster and smoke-producer of phosphorised antimony.

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Page 233.—The Austrian gun is further described on page 252.

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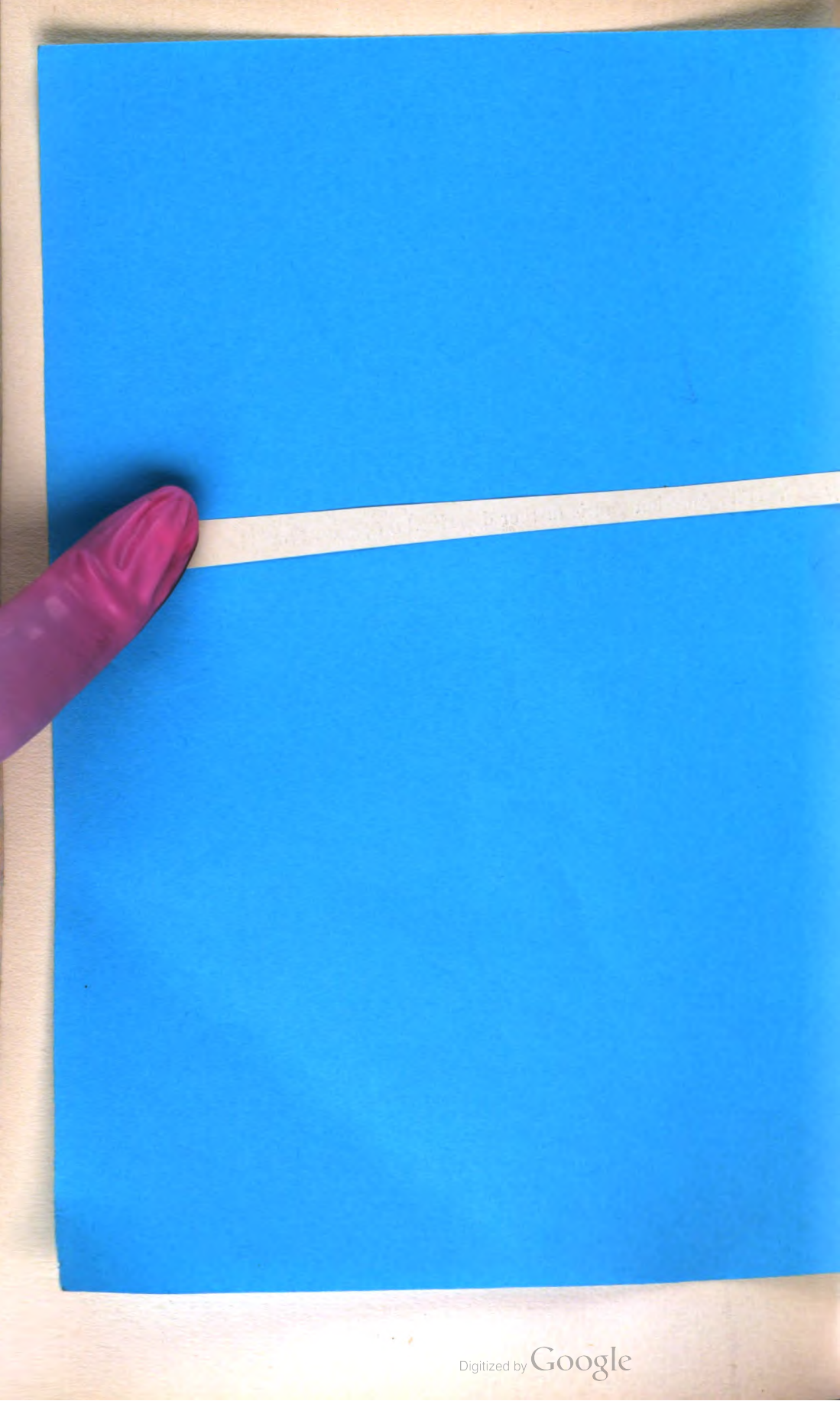

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The exact weight of the shell is still doubtful. Major Kühn gives the weight of the shell as 14.3 lbs., M.V. 1945 fs. The 14.3 lb. shell is said to contain only 260 bullets of 42.5 to the pound, with a smoke-producer and 3 oz. driving charge.

The Russian fuze is similar in principle to the double-banked fuze illustrated on page 69, but the gases escape at the point of the fuze, which is hooded to protect the escape-holes from the air-pressure in flight. This precaution is very necessary in view of the high velocity of the shell.

Stability of Gun in Action.

Taking the values in the Table:—

Recoil velocity	34.4 f.s.
Recoil energy	7.803 ft.-tons
Average pull on carriage	2.366 tons
Height of C.G. of recoiling parts above centre of spade	40″
Overturning moment, average	7.803 ft.-tons
Steadying moment, average	8.22 ft.-tons

Therefore the gun has a certain amount of stability in hand at point blank elevation.

General Remarks.

Except the new high-velocity Krupp gun, the new Russian gun is the most powerful field gun in existence. It is somewhat heavy, but the design seems simple and serviceable. No great rapidity of fire is to be expected from it. According to Captain Alexandrovitch it recoils about 1 foot at the first round, and about 1 inch at each succeeding round.

The buffer, being completely filled with oil, tends to suck in air through the gland on recoil; this prevents the gun from fully running up, and the air has occasionally to be run off by a screw-plug fitted for the purpose.

Dragshoes are cumbrous things to use.

By using a cranked axletree the designers have succeeded in keeping the gun low, and in securing steadiness in spite of the high muzzle energy and comparatively short recoil.

Altogether the design seems a good one, presenting many points worthy of imitation.

THE AUSTRIAN Q.F. EQUIPMENT.

It is still uncertain which of the various equipments under trial has been adopted by the Austrian Government. The following information is believed to be correct.

The gun is of bronze, calibre 3.01 inches, M.V. 1640 fs., weight of shell 14.72 lbs. It is of unusual length, said to be 32 calibres. It is also said to have semi-automatic breech mechanism of interrupted screw type, but this is doubtful. The gun is mounted on a cylindrical cradle, open at top, with the guides inside it; the cradle contains the buffer and telescopic (?) springs. The cradle traverses on a vertical pivot.

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The Austrians are said to favour the *forward pivot* system, in which the cradle pivot is well forward towards the muzzle.

Presumably this construction has some advantages, or it would not be adopted. But it would appear to increase the tendency of the carriage to shift when the gun is fired at extreme traverse.

The gun fires fixed ammunition and is sighted with an arc sight and a panorama sight. The shield is 4 mm. thick and has a folding top similar to that of the German shield. Axletree seats are fitted. The wagon is shielded, and will be unhooked (not unlimbered) beside the gun in action.

Further details are given in the Table.

THE ITALIAN 1902 SEMI-Q.F. EQUIPMENT.

This gun may be said to have become obsolete before it was introduced. It is a 75 mm. Krupp gun on rigid carriage. It has a spring spade and spring drums on the naves of the gun wheels, around which ropes attached to the brake blocks are coiled; these drums revolve the wheels forward after recoil is completed and so run the carriage up.

The gun has no shield.

The best part of the equipment is the gun, which is said to be remarkably accurate; it has a M.V. of about 500 metres (1640 fs.) and fires separate ammunition, including shrapnel and H.E. shell; the shrapnel weighs 14.74 lbs. and contains 140 bullets of 41 to the pound and 180 of 45 to the pound. A Krupp double-banked aluminium fuze is used.

The Italian Government officially announced in May, 1904, that the semi-Q.F. Equipment no longer satisfied the requirements of modern military science, and that it was proposed to introduce a shielded long-recoil Q.F. equipment of the Krupp type. The conversion of the artillery to the semi-Q.F. pattern had been discontinued.

The Italians have been trying Krupp guns of several calibres, namely 70 mm., 73 mm., 75 mm. and 76 mm. The two former have been discarded. The details of the 75 mm. gun are given in the Table. It is of the same power as the Swiss gun.

THE SWISS 1903 Q.F. EQUIPMENT.

This was the first gun-recoil equipment made by Krupp, and has proved a very serviceable one. The gun is only of moderate power, the ballistics being the same as those ot our 1893 15 pr. B.L. gun. It is very steady in firing and has good shield protection. It has the wedge breech-action and fires fixed ammunition. It has not the independent line of sight.

The carriage is of the usual Krupp pattern, as shown in Fig. 100. It has a cradle under the gun with buffer and single column of springs

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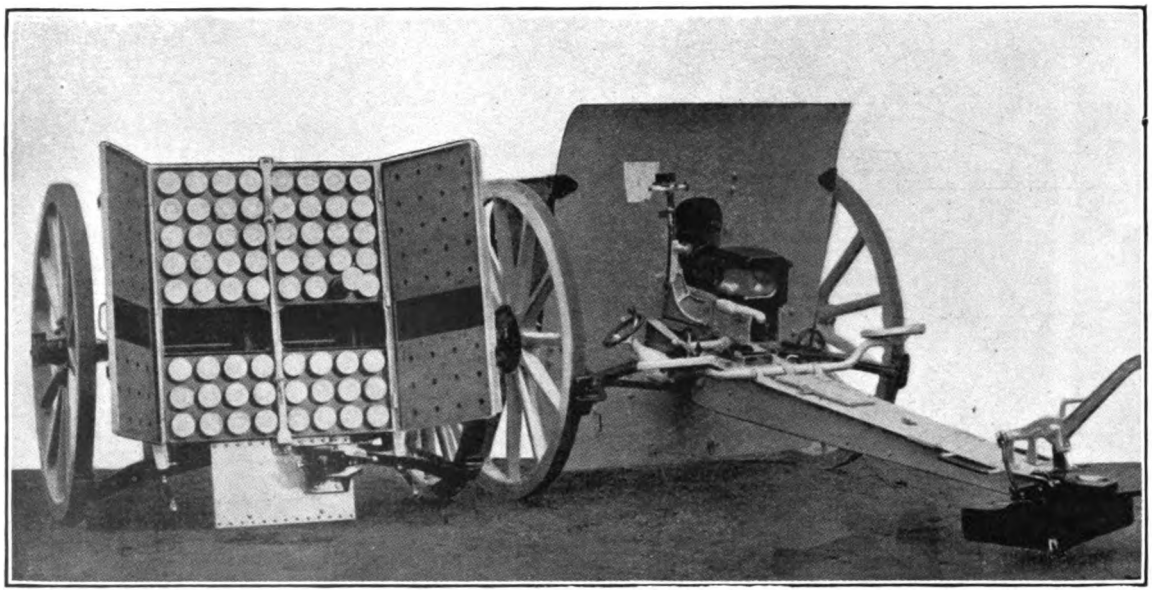

Fig. 100.

THE SWISS Q. F. GUN.

KRUPP.

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as shown on page 223. The cradle traverses on a vertical pivot set in a saddle between the trail brackets somewhat forward of the axle. The elevating gear is a plain double screw.

The original shrapnel has been replaced by a Swiss shrapnel with heavy bullets, as described in the chapter on Shrapnel Fire. The high-explosive shell is filled with the same nitro-powder as is used in the cartridge.

The wagon body is armoured and is tipped alongside the gun as in the French equipment.

The track of the Swiss gun is too narrow to admit of axletree seats being used. Two gunners are carried standing.

The following details have been published in addition to those given in the Table:

Height of axis of gun	39 in.
Track	55 in.
Width of tire	2¾ in.
Weight of carriage with accessories	13 cwt.
Pressure of trail on ground ...	154 lbs.
Weight of limber	15¾ cwt.
No. of rounds carried	40.
Wagon, weight	36½ cwt.
Wagon, rounds carried ...	96.
Shield, area of, square feet ...	20.5
Shield, thickness of, $\frac{5}{16}$″ or ...	4¾ mm.
Shield, weight of	167 lbs.

THE SPANISH 1903 Q.F. EQUIPMENT.

Spain has had several experimental Q.F. equipments under trial, including guns made by Krupp, Schneider-Canet, St. Chamond, and Vickers-Maxim. The latter is now superseded by the Creusôt (Schneider-Canet) gun afterwards described. It is a shielded Q.F. gun with buffer on top of the gun and two sets of telescopic running-out springs, one set on each side of the buffer. The gun is sighted with the Goerz Panorama Sight, and has the independent line of sight. The breech mechanism is a new type of swinging block, very like that in the American 1903 Q.F, gun. It has a percussion lock, and fires fixed ammunition, both shrapnel and H.E. shell. The fuze is the Krupp double-banked fuze.

The details of the Vickers-Maxim gun are as follows—

Calibre	7.5 cm. or 2.95″
Muzzle velocity	1706 fs.
Weight of fuzed shell	14.33 lbs.
Length of gun	7′ 8″
Length of trail	7′ 9″
Description of trail	Box trail
Height of wheels	4′ 8″
Track	5′
Weight of gun and limber equipped without men	35½ cwt.
Weight of gun in action ...	23⅛ cwt.

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THE PORTUGUESE Q.F. EQUIPMENT.

(See Fig. 101.)

(This equipment has also been adopted by Spain.)

This is interesting as being the latest example of the hydro-pneumatic type of Q.F. gun. It was selected after a competitive trial with a Krupp gun of the same power.

The gun is 31.4 calibres long. It has a plain buffer and check-buffer, and a separate running-up piston actuated by compressed air. A steel forging is fixed to the gun and recoils with it; this forging has four holes bored in it, namely one forming the buffer, one forming the running-up cylinder, and two forming compressed-air reservoirs. The buffer-piston and running-up piston are attached to the cradle. The cylinder in which the latter piston works is filled with glycerine, which prevents the compressed air in the reservoirs (which communicate with the cylinder) from escaping through the gland. The air is under a pressure of about 23 atmospheres or 340 lbs. per square inch.

There is one peculiarity about the hydraulic buffer. The recoil is not regulated in the usual way by allowing the glycerine to pass through ports of varying depth in the walls of the buffer-cylinder. Instead of this, two projecting ribs of varying width are formed on the inner surface of the cylinder. These fit into and partly close two recesses or notches in the piston. The glycerine has to flow through the portions of the notches which are not closed by the ribs. This construction was used in our own coast mountings 30 years ago.

The gun is an axle-traverser on the same system as the French gun, and is sighted in the same way, except that the *collimateur* is replaced by a prismatic telescope. The gun has the independent line of sight.

All graduations are in thousandths, and the battery telescope has a graticule showing thousandths of range. The sight has a lengthening stem and can be raised for laying from behind a crest.

By attaching the forging containing the four cylinders to the gun, the recoiling weight is increased to 8.84 cwt.; this reduces the recoil and so promotes the stability of the carriage.

The weight of the gun is kept very low down, the height of the axis being only 37.5 inches. This is due to the flat shallow section of the forging containing the recoil gear.

The extra length of the gun enables the chamber pressure to be reduced for the same muzzle energy. The breech action is the Schneider interrupted screw.

To traverse the gun the trail, carrying with it the cradle, the gun, the shield, and the two numbers on the seats, is shifted along the axletree by worm gear. The total traverse is 3 degrees each way, or 6 inches each way along the axletree. Hence the shield must be 6″ clear of the wheels on each side. To get sufficient width of shield for protection the track is 5′ 2″ from centre to centre, which is about 3″ wider than in most field guns.

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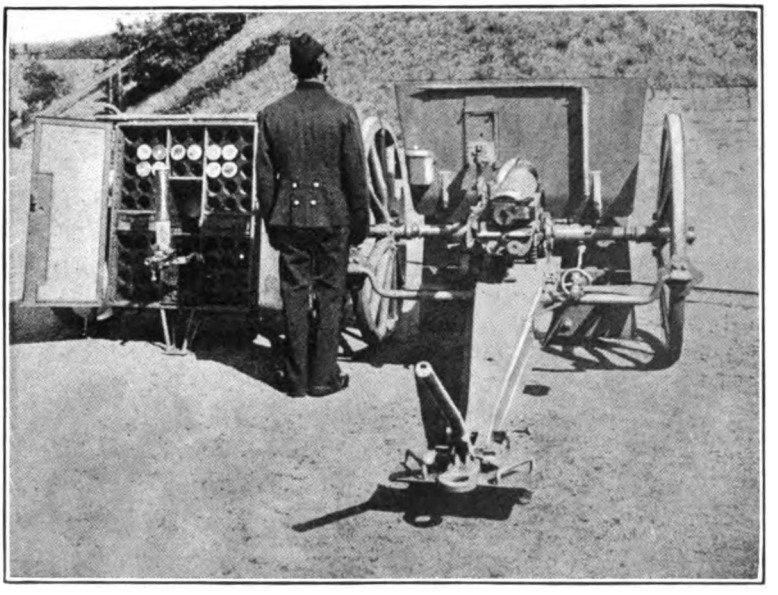

FIG. 131.

SCHNEIDER-CANET HYDROPNEUMATIC Q. F. GUN.

SPAIN AND PORTUGAL.

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The shield is 4 mm. thick, of special steel, and is said to keep out the French D bullet at a range of 40 yards.

The wagon body is tilted alongside the gun as in the French equipment; it is armoured with steel of the same thickness as the gun-shield.

It is understood that the gun, as finally accepted by the Portuguese and Spanish Governments, has not the shoes under the wheels which characterise the French gun. These shoes are replaced by an ordinary travelling brake, which must however be slackened to traverse the gun. The gun therefore requires no *abatage*. Presumably this simplification is rendered possible by the fact that the muzzle energy is much less than in the French gun, namely 266 foot-tons as against 333.

The carriage has axletree seats, but these are small and only intended to be used on emergency, the idea being to carry 3 gunners on the limber.

The limber has both spring draught-loops and a spring limber hook.

The weights of the equipment as submitted to the Portuguese Committee are given in the Table. But it is stated that these have since been somewhat increased, as the carriage and limber (especially as regards the wheels) were found too light for the Portuguese roads.

In addition to the ordinary fittings, the following are carried: an air-pump, a glycerine pump, (similar to a bicycle pump) and a pressure-gauge.

The gun fires fixed ammunition, including shrapnel and (probably) high-explosive shell. The latter if adopted will contain a burster of 4 oz. of the same powder as used in the gun, which is a guncotton powder. The fuze is on the same principle as the French fuze illustrated in the chapter on Ammunition, and is set by a double fuze-punching machine. The gun is capable of firing 25 rounds in one minute with fuzes set beforehand, or 18.5 rounds per minute of searching and sweeping without setting fuzes beforehand.

The following details have been published in addition to those given in the Table:—

Length of rifling	77 inches
Number of grooves	24
Twist, uniform right-handed	1 in 30
Weight of breech action	26.8 lbs.
Height of axis	37.5 inches
Height of line of sight	44.5 inches
Trail lift	1.72 cwt.
Weight of one round	18 lbs.
Weight of shrapnel burster	2.8 oz.
Pressure in bore, maximum	12.7 tons
Number of rounds in wagon limber	38
Number of rounds in wagon body	72

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THE NORWEGIAN 1899 Q.F. EQUIPMENT.

This gun is made by Messrs. Ehrhardt, and is practically the same as the 15-pr. Q.F. gun supplied by the same firm to England, the chief difference being that the breech action is the Nordenfeldt eccentric screw instead of the interrupted screw. The gun has been fitted with a folding shield 4′ 6″ high, and 3½ mm. or 0.14 in. thick, which is carried on the wagon.

THE SWEDISH 1904 Q.F. FIELD EQUIPMENT.

This is manufactured by Krupp, and is understood to be practically identical with the Danish gun described below.

The Swedes have been experimenting with the new French fire discipline in connection with their new gun, and have decided to adopt its leading features, namely ranging with time fuze, *tir progressif et fauchant*, and the *rafale*. With their new equipment, which is organised in four-gun batteries, the Swedish artillery are able to fire a series of 48 rounds of *tir progressif et fauchant* in 1½ minutes, without setting fuzes beforehand.

THE DANISH 1904 Q.F. EQUIPMENT.

This is a 75 mm. gun, of Krupp's 1902 model, as illustrated in Fig. 102.

The following particulars are given by the Mittheilungen des Artillerie und Geniewesens:—

The gun is more powerful than the Swiss and Dutch Krupp guns, firing a shell of 14.85 lbs. with M.V. 1640 fs. It has an unusually long recoil, namely 58 inches. The gun is mounted on the usual Krupp cradle, pivoted for traversing on a vertical pivot set in a saddle between the trail brackets. The cradle contains the buffer, which recoils with the gun, and is surrounded by a single column of springs. The breech action is the single-motion wedge. The gun is sighted with the Krupp telescopic sight illustrated on page 17. The elevating gear is a plain double screw under the traversing plate, which is a rearward continuation of the saddle. The firing gear is a repeating trip-lock; the gun fires fixed ammunition.

The shield consists of an upper and a lower portion. The upper portion may be removed and carried on the wagon for travelling; the lower portion is hung from the axletree. It is not continuous, but is in two parts, one on either side, which can be folded up backwards for travelling. The shield is said to be 6 mm. or 0.236″ thick.

The wheels are 4′ 4″ in diameter. Axletree seats are provided, but three men can be carried on the limber. The limber is divided into 12 compartments, of which 11 contain baskets with 4 rounds; the 12th compartment contains tools and an automatic fuze-key. The

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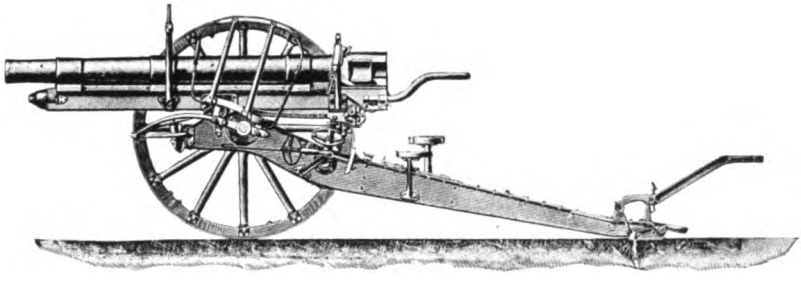

FIG. 102.

75 mm. Q. F. GUN, KRUPP, 1902.

Shield not shown.

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wagon limber is similar, but carries 12 baskets. The wagon body is of the French type and is tipped alongside the gun in action. The doors then open outwards. The bottom of the wagon is armoured with a 6 mm. plate, the doors with 3 mm. plate, The wagon body holds 72 rounds.

A pyramidal observation ladder can be mounted on the wagon. It weighs 48 lbs. and raises the height of the observer's eye to 10 ft.

The above-quoted journal gives the weight behind the team, without gunners, as 38 cwt. for the gun and 40 cwt. for the wagon. This is unusually high.

The following details are given in addition to those in the Table:

Height of axis	... 39.5 inches
Height of line of sight ...	... 49 inches
Weight of wheels ...	... 143 lbs.

THE DUTCH 1904 Q.F. EQUIPMENT.

This is a Krupp field gun of very moderate power. It is of the characteristic Krupp construction described in the next chapter. The trail is shorter than the Ehrhardt, namely 8′ 9″ as against 10′.

The shell weighs only 13.2 lb., and the M.V. is 1640 fs., giving a muzzle energy of 245 foot-tons, or slightly more than the 15-pr. B.L. gun. The equipment is not specially light, weighing 34½ cwt. behind the gun team without kits and without gunners. The Committee who selected it were impressed by the steadiness of the carriage in firing. Considering the low muzzle energy, it is not surprising that a high degree of steadiness was attained.

There is practically no advantage in having the carriage absolutely steady during firing so as not to require any re-laying. All that is really necessary is that the amount of motion should be so small that the layer is able to correct it in the 3 or 4 seconds available before the next round is fired.

The principal details of the Dutch gun are given in the Table.

The following particulars have also been published:

Height of axis of gun	36¾ in.
Weight of carriage	11¾ cwt.
Weight of limber without equipment	15¼ cwt.
Weight of gun and limber without men, kits, or equipment ..	34½ cwt.
Weight of powder charge ...	15¾ oz.
Effective range with shrapnel ...	6200 yards.
Effective range with H.E. shell ...	7000 yards.
Weight of wagon without men, kits, or equipment	35½ cwt.
No. of rounds in wagon	104
Rate of fire per minute	20 rounds.

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THE BELGIAN Q.F. EQUIPMENT.

This gun is a Krupp 14.3 pounder, M.V. 1640 fs. It is intermediate in weight and power between the Krupp guns made for Switzerland and for Denmark. It is of the ordinary Krupp build with buffer and single spring-column under the gun. It is fully shielded with a 5 mm. shield. It has a panorama sight, but not the independent line of sight. The Belgians have imitated the Austrians in adopting the small shrapnel bullet, 50 to the pound. The idea is presumably that even a slight wound is sufficient to temporarily disable a civilized soldier, when he becomes a greater encumbrance to his side than if he were killed outright.

The gun fires fixed ammunition; the powder is Coopall's leaf powder.

The wagon is shielded, and is unhooked, not unlimbered, beside the gun in action. In addition to the rear door of the ammunition box, which hangs down to the ground, the box has two side doors opening outwards which give additional shield protection.

Details are given in the Table.

GREECE.

Greece is proposing to get her old Krupp guns converted to the Q.F. system, but nothing has yet been done.

THE TURKISH 1904 EQUIPMENT.

This gun is a Krupp 13.2 pounder, generally similar to the Dutch gun. But if the published ballistics are correct, the muzzle velocity is only 1590 fs. The Turkish authorities required the gun to be fitted with plain arc sights only; there are no goniometric or panorama sights, and there is no means of laying the gun behind cover.

The following details are given in addition to those in the Table:

Trail lift	... ...	125 lbs.
Shrapnel bursting charge	...	2.65 oz.
Powder, Rottweil D.F.P.	...	75 × 1½

THE BULGARIAN Q.F. EQUIPMENT.

This is by Schneider of Creusôt. It differs from his ordinary construction in that running-up springs are used instead of compressed air. Otherwise the gun is very similar to the Portuguese and Spanish guns.

It is reported that the order for the greater part of the ammunition has been given to Krupp.

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The following details are given in addition to those in the Table:

Weight of empty limber	...	7.25 cwt.
Weight of 1 round ...	...	18.05 lbs.
Weight of charge, B. N. powder	...	1.275 lbs.
Weight of shrapnel burster	...	2.8 oz.
Weight of H.E. shell burster, nitro-powder	...	4 oz.
Remaining velocity 1000 metres	...	1230 fs.
2000 „	...	996 „
3000 „	...	890 „
4000 „	...	817 „
5000 „	...	761 „

Hence the ballistic coefficient at 3000 metres is 1.75, and n is 0.94.

SERVIA.

According to the German Press, Servia has been trying guns made by Krupp, Ehrhardt, Skoda, Schneider, and St. Chamond. It is reported that the English firms withdrew from the competition, and that the order has been given to Schneider. The Schneider gun is very similar to that made for Bulgaria.

THE ROUMANIAN 1904 Q.F. EQUIPMENT.

(See Figures 96, 103 and 104).

This is a characteristic Krupp gun, being a 75 mm. 14.3 pounder, M.V. 1640 fs.

The gun is of nickel steel, 30 calibres long, increasing twist, and has the Krupp single-motion wedge breech action. In this case it has no foresight, but the Ghenea panoramic sight, mounted on a pedestal, is used both for direct and for indirect laying. The gun has not the independent line of sight.

The cradle is under the gun and contains the buffer and running-up springs. These have been illustrated under the heading of the German gun. The buffer is under the gun, and consists of a cylinder 0.3″ thick, 2¼″ internal diameter, nearly filled with glycerine. In the cylinder works a piston attached to the cradle, passing through a gland in the head of the buffer. The buffer is secured, by the compressor screw afterwards described, to a horn under the breech of the gun. The maximum recoil permitted is 54 inches.

The buffer is carefully bored, not for uniform resistance but for uniform stability of the carriage. For the first two inches of recoil, while the shell is still in the bore, the windage between buffer and piston is so large as to oppose hardly any resistance to recoil. The cylinder is then constricted so as to oppose the full resistance to recoil while the gun is still in the forward position and the stability

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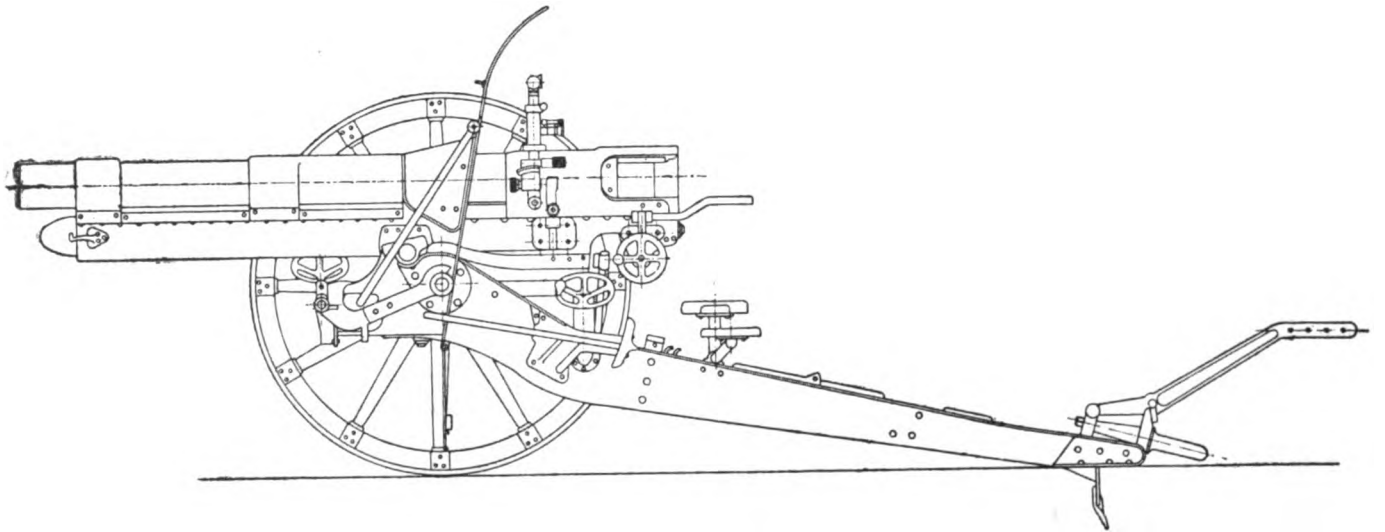

FIG. 103.

THE ROUMANIAN Q.F. GUN. KRUPP.

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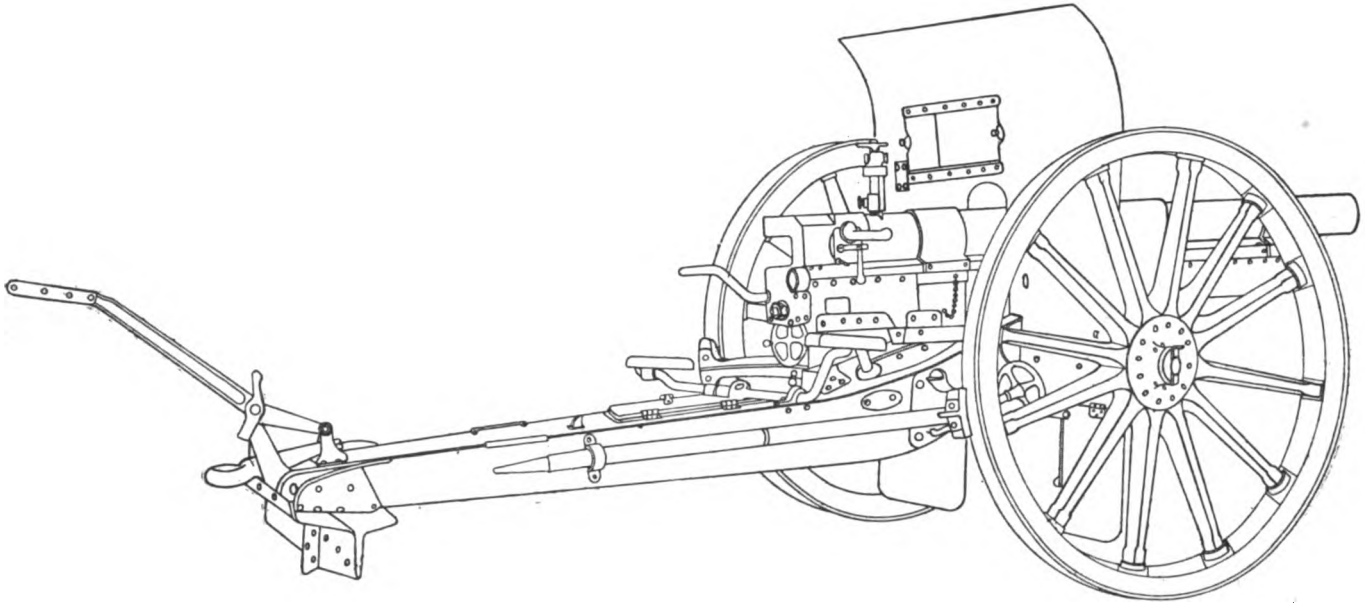

FIG. 104.

THE ROUMANIAN Q.F. GUN. KRUPP.

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of the carriage is at its greatest. The windage is then gradually increased so as to diminish the buffer-resistance as the gun moves back and the centre of gravity of the system shifts towards the spade. A further allowance is made for the resistance of the springs, which also help to check the recoil. The result is that the curve of total resistance to recoil is parallel to the curve of stability and at a constant distance below it.

This construction gives remarkable steadiness with a comparatively short trail.

So far the windage between buffer-cylinder and piston has been spoken of as if it were a simple difference of diameter. This construction might be possible if oil were used as buffer-liquid, as the windage required would then be small. But with glycerine, which is a more viscous liquid, the difference of diameter would be so great as to leave the piston and piston-rod unsupported, causing wear and leakage at the gland. Actually, the piston is a close fit in the buffer and the glycerine passes the piston by channels of varying depth and about 1 centimetre wide cut in the inner surface of the cylinder. These channels are not straight but spiral, being used also to control the Vavasseur valve described below.

The Krupp Running-up Gear. Krupp employs a single column of running-up springs, surrounding the buffer, of the special steel already described. The spring-column is 6′ 9″ long and the recoil 54 inches, so that the springs are compressed to 1/3 of their working length at every round. This is a severe degree of compression, and is only rendered possible by the extraordinarily high quality of the steel. The springs are of flat section and are only strong enough to lift the gun and recoiling parts, little surplus power being required to overcome the buffer-resistance in running up, as in some other equipments. The buffer-piston has a valve opening forward which allows the glycerine to pass freely during running-up. This valve however requires to be controlled, otherwise the gun would run up with such force as to jerk the spade out of the ground. A Vavasseur control-valve is accordingly fitted to the rear face of the piston. This valve consists of a disc which, as it revolves, opens or closes the inlet to the running-up valve. It is controlled by two of the channels or grooves in the inner surface of the cylinder, in which two projections from the disc engage. The grooves are so inclined that as the gun runs up the check-valve gradually closes, bringing the gun gently to a standstill. This arrangement does away with the necessity for the check-buffer used in other equipments.

Initial Compression. The effective length of the buffer-cylinder in the Krupp equipment is 79″, the length of recoil only 54″. This leaves 25″ of cylinder to spare, besides the length occupied by the buffer portion. This extra length of cylinder is used to receive the screw which gives the initial compression to the springs. A stout screw 2 feet long projects forward from the horn on the breech of the gun; the buffer and springs (which, uncompressed, are 9 feet long) are placed in the cradle from the front, and pressed in by hand till the screw enters a nut at the rear end of the buffer-cylinder. The screw is then turned by a handle until the rear end of the buffer-cylinder is drawn into the horn.

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The initial compression of the Krupp springs is 5 cwt., following the German manufacturers' rule that the initial compression should be 80% of the weight of the gun. It is calculated that one kilogramme of steel spring can absorb and give out 12 kilogrammetres of work, after making all practical deductions.

Re-filling Buffer. Owing to the construction of the Krupp buffer the rear end is inaccessible, the end of the cylinder being occupied by the compressor screw. The buffer is therefore filled from the stuffing-box end. The whole stuffing-box, containing the gland and packing, is unscrewed, without disturbing the packing, and the buffer re-filled with glycerine when required. Krupp maintains that it is as easy to unscrew the stuffing-box as to unscrew a filling-plug.

The cradle is pivoted vertically in a saddle, which is prolonged to the rear to form the traversing bed. The saddle itself is pivoted horizontally on trunnions between trail brackets. By setting these trunnions forward of the axletree the carriage is balanced and the trail lift kept down to 154 lbs. The elevating gear is of the ordinary double screw type. The trail is of the box pattern, slightly bent to give room for the elevating gear. It has the characteristic Krupp spade. The trail eye has a spring attachment to the trail. The wheels are a Krupp speciality. The felloes are bent, and are not weakened by boring for the tenons of the spokes. Instead of this they carry steel spoke-shoes into which the feet of the spokes are inserted. The brakes are of the ordinary pattern, but the handle is on the muzzle side; they are apparently intended for travelling only. There are no axletree seats.

The shield is a remarkable feature of the gun. It is 6 millimetres or nearly ¼ inch thick, and stands 5′ 9″ from the ground. Notice in the figures the conical hood projecting forward from the shield. The object of this forward projection is to keep the shield well back for protection and yet to bring the aperture through which the gun passes as near as possible to the horizontal and vertical trunnions on which the gun pivots, so as to reduce the opening to a minimum. Notice also the large shuttered window in the shield for convenience of laying. The lower shield is in two separate portions, one on either side of the trail. The shield is supported by two stays fixed to the front prolongation of the trail. In spite of the heavy shield the gun weighs only 21 cwt. in action.

Sights. The Ghenea pedestal sight is pivoted on a transverse horizontal pivot, and is always perpendicular to the line of sight. The angle of elevation, which corresponds to the inclination of the axis of the piece to the line of sight, is read on an arc scale and micrometer. The longitudinal level is just over the eye piece of the panorama sight; it is capable of adjustment for angle of sight. It is to be presumed that the saddle trunnions are inclined to compensate for drift, but there is apparently no means of compensating for difference of level of wheels.

The limber holds 24 rounds and is seated for three; the weight of gun limbered up is only 33.8 cwt. without men or kits.

The wagon body holds 64 rounds and is tipped beside the gun in action. Weight of wagon without men or kits 35 cwt.

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An observation ladder weighing 55 lbs. is carried on one of the wagons.

Ammunition. The gun fires fixed ammunition. The shrapnel is of the ordinary type and contains exactly 50% of bullets besides a burster of 2.65 oz. and a smoke-producing charge.

The high-explosive shell is not of the ring type illustrated in Chapter IX; it is a plain thick-walled shell with a central primer surrounded by a bursting charge of 4.93 oz. nitro powder; this again is surrounded by a layer of smoke composition. The double-banked T. and P. fuze weighs 13.8 oz., and the percussion fuze used with the H.E. shell weighs 12 oz.

The following particulars are given in addition to those in the Table—

Total length of gun	7.37 feet.
Twist, increasing from 1 in 50 to 1 in 30.	
Track, centre to centre	4.85 feet.
Trail lift	154 lbs.
Rounds in gun or wagon limber ...	24.
Rounds in wagon body	64.
Thickness of gun-shield ...	6 mm.
Thickness of wagon shields ...	5 and 3 mm.
Weight of one round	18.75 lbs.
Length of shrapnel	3.5 calibres.
Weight of shrapnel empty ...	5.76 lbs.
Weight of 295 11-gramme bullets ...	7.15 lbs.
Weight of shrapnel burster ...	2.65 oz.
Weight of T. and P. fuze ...	13.8 oz.
Weight of high-explosive shell, empty	13.25 lbs.
Weight of nitro-powder burster ...	4.93 oz.
Weight of percussion fuze ...	12 oz.

THE AMERICAN 1903 Q.F. EQUIPMENT.

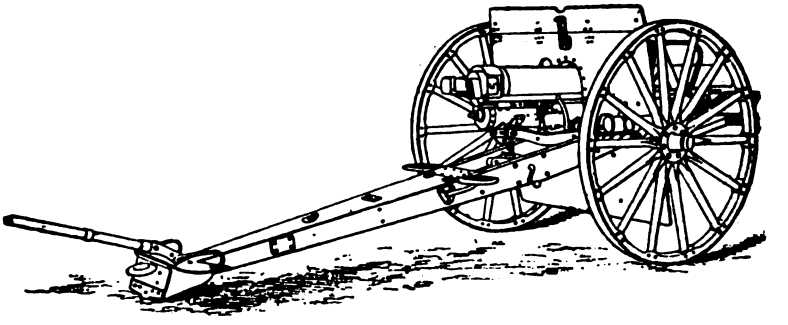

FIG. 105.

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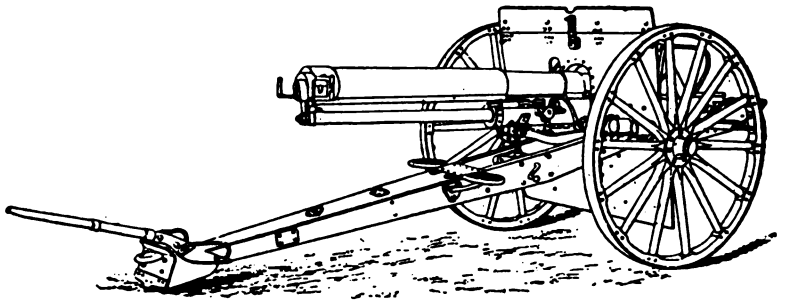

FIG. 106.

This is a modernized version of the 15-pr. Q.F. Ehrhardt gun as supplied to England. It has the Ehrhardt buffer and cradle with vertical trunnion, and a non-telescopic box trail 10 feet long. It has the Gerdom swinging block breech mechanism, with eccentric striker (see Chapter on Breech Actions). It has a percussion lock and fires fixed ammunition, with an Ehrhardt double-banked fuze.

The shield is of special hard chrome-nickel steel, and resists penetration by the powerful American rifle at 100 yards. It is 5 millimetres or 1/5 of an inch thick, and has a folding flap at top which when erected stands 1 foot above the level of the wheels, which are 4ft. 8in. in diameter.

Four rounds are carried in steel tubes under the axletree seats. The limber is built to seat 3 gunners, though only two will ordinarily be carried on it.

The powder at present used with the American gun is cotton nitro-cellulose of 12.65% nitration, 99% soluble in ether alcohol. This powder is said to deteriorate after two years in store.

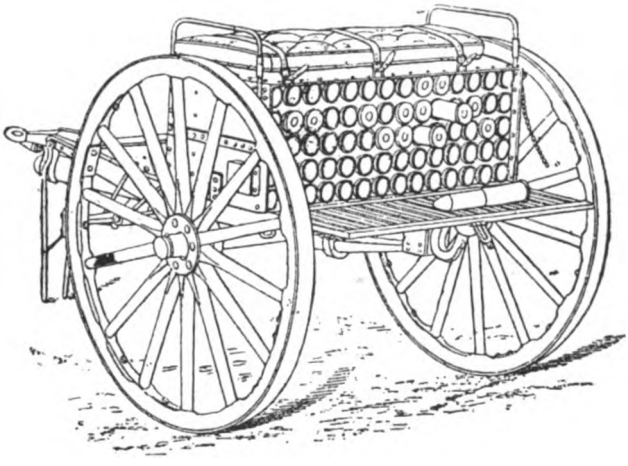

FIG. 107.—WAGON BODY.

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The Journal of the U.S. Artillery gives the following particulars—

Muzzle velocity	1700 fs.
Extreme range with shrapnel ...	6500 yards.
Weight of one round	18¾ lbs.
Length of gun	7ft. 3½ in.
Number of wagons per gun ...	3.
Number of rounds carried per gun ...	358.
Weight of limber empty	8 cwt.
Weight of 36 rounds	6 cwt.
Weight of wagon empty	17¼ cwt.
No. of rounds in wagon	106.
Weight of 106 rounds	18 cwt.
Weight of wagon behind team without gunners	35¼ cwt.
Ditto, with 6 gunners	44 cwt.
Weight of gun behind team without gunners	34¾ cwt.
Ditto, with 3 gunners	39½ cwt.

The latest accounts state that the Americans have had to strengthen their gun wheels by making the felloes deeper. The extra weight is about 12 lbs. per wheel. They have also introduced a fuze-setting machine.

THE MEXICAN SEMI-AUTOMATIC Q.F. GUN.

(See Fig. 108.)

This is a high-velocity 13 pr. partly designed by Col. Mondragon of the Mexican Army, and manufactured by St. Chamond. It is a semi-automatic gun; that is, the breech opens automatically during running-up and ejects the empty cartridge case. The breech then remains open till the gun is loaded; when the extractor is pressed home in the act of loading the breech closes automatically by a spring. The action is similar to that of the Krupp semi-automatic mountain gun afterwards described.

The semi-automatic action has been applied to light naval guns by Elswick, Vickers-Maxim, and the Coventry Ordnance Works in England, and by most of the great Continental firms. But the Mondragon gun is the only instance of its application to field artillery, with the possible exception of the new Austrian gun. It enables one of the men at the gun (the breech-closing number) to be dispensed with.

(It may here be noted that the French field artillery gun is practically semi-automatic. The gun recoils so that the breech is within reach of the "chef de pièce," standing at the point of the trail, and it is customary (though not regulation) for him to throw up the lever of the eccentric screw, so that the gun when it returns to the firing position is ready for loading,)

The Mexican gun is fully shielded with 5 mm. shields of chrome-nickel steel. The gun is run up by springs, not by compressed air. The peculiar method of attachment of the gun to the buffer, as seen in the photograph, is a St. Chamond speciality, and increases the

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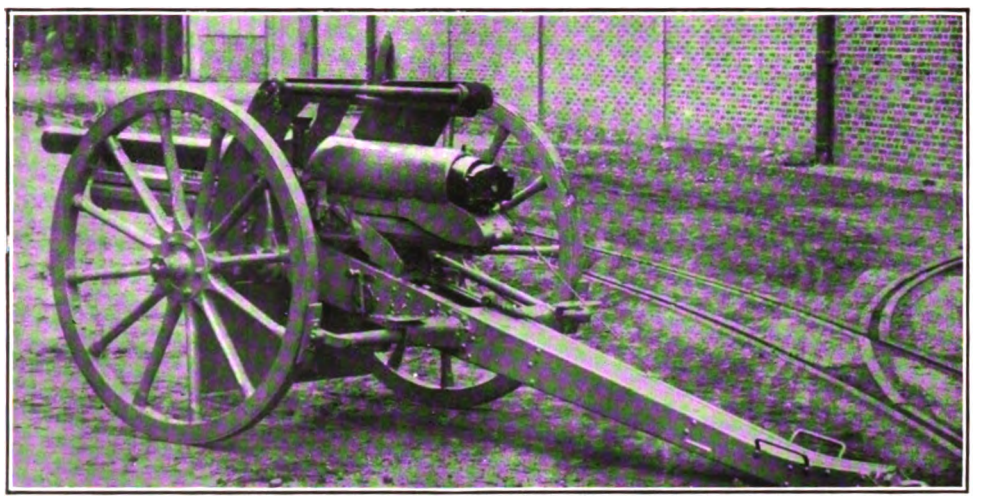

Fig 108.

THE MEXICAN Q. F. GUN.

ST. CHAMOND

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effective length of the spring-column. The gun has a long box-trail, bent near the point, so as to allow of 16° of elevation being given. The spade is narrow and pointed, as in the French gun. The gun traverses on a central pivot. It is sighted with a panorama sight, and fires fixed ammunition.

The weight of the gun behind the team is given at 36.25 cwt., that of the wagon at 37.3 cwt. This includes all equipment but not gunners.

The details are given in the Table.

The old Mexican 80 mm. (3.15″) B.L. guns have also been converted to quick-firers by the St. Chamond firm.

THE BRAZILIAN 1904 Q.F. EQUIPMENT.

This is a light 13 pr. equipment made by Krupp. The gun in action weighs only 16 cwt., and the wagon only 25 cwt. The gun and wagon have 4½ millimetre shields. The gun is of moderate power; it fires fixed ammunition, and has not the independent line of sight. The breech action is the Krupp wedge.

Details are given in the Table.

CHINA.

It is reported that China has ordered 36 75-millimetre guns from Krupp, 36 field and 18 mountain guns from Schneider of Creusôt, and has bought 110 guns from Japan. These are some of the light Arisaka guns used in the war. The Krupp gun selected is said to be similar to the Brazilian gun.

THE JAPANESE 1901 B.L. EQUIPMENT.

(See Fig. 109.)

This gun was designed by Col. Arisaka, and manufactured partly by Krupp, partly at Osaka, in Japan.

It is a light 75 mm. gun, adapted to be drawn by Japanese ponies. It is not quick-firing, but the recoil is reduced to a minimum by large dragshoes and a spring brake.

The breech-closing mechanism is of the interrupted screw type, the breech-block being pivoted horizontally, so that it opens backwards and downwards.

Separate brass case ammunition is used, fired by a percussion lock.

The weight is kept very low; the axletree is in one piece with the gun, the trunnions being extended to form the axletree arms. In view of the rough ground on which the gun has to be used, the carriage is designed to allow a range of elevation and depression of 25 degrees.

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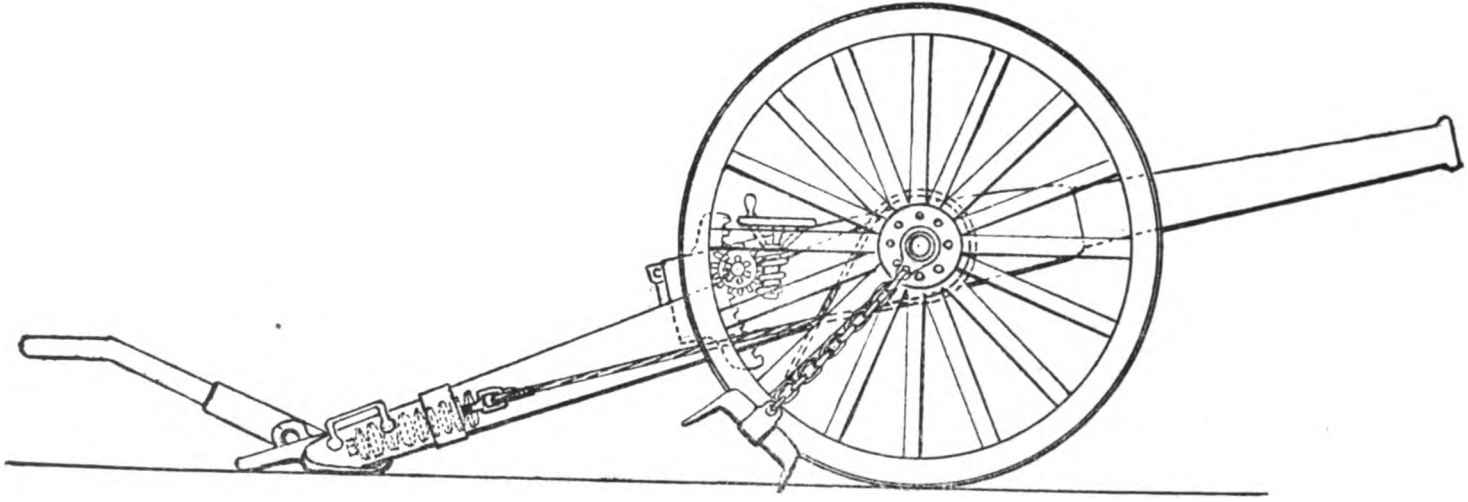

FIG. 109.

THE JAPANESE FIELD GUN.

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The recoil is checked by large wedge-shaped dragshoes under the wheels; to these are attached wire ropes passing round drums inside the naves of the wheels and connected to a strong spring between the brackets of the trail. On recoil the wheels revolve backwards and the spring is extended; after recoil the spring contracts and rotates the wheels forward, tending to run the gun up again.

At the beginning of the present war the Japanese gun had no shield. But after the battle of Liao-Yang some at least of the Japanese batteries were fitted with gun-shields of boiler-plate. These shields may be noticed in photographs of the Japanese artillery on the Sha-Ho.

The ammunition consists of shrapnel and high-explosive shell; the latter has a bursting charge of picric acid, and a base percussion fuze with centrifugal safety. The fuze has a detonator of 40 grains of fulminate composition, and a primer of 2 oz. picric powder.

The details of the equipment are given in the Table.

THE JAPANESE 1907 Q.F. EQUIPMENT.

The Japanese are dissatisfied with their light 1901 gun, the shooting of which compared badly with that of the powerful Russian gun to which it was opposed. They are now trying several guns, including the E.O.C. 13 pr. described in the next chapter, and a Krupp 13 pr. similar to the Dutch gun. Their new equipment will be made to their own design, and will probably be generally similar to the Krupp. The Krupp design will be lightened by omitting the axletree seats; the limber will be of light pattern carrying about 24 rounds only. The track will be much less than that of the European guns, probably not exceeding 4′ 6″. The gun will certainly have a shield.

German Press accounts state that the Krupp design has been finally adopted, but this statement must be received with caution.

HORSE ARTILLERY GUNS.

Most nations consider that the difficulty of supplying two different natures of ammunition on the battlefield is a bar to the introduction of a special Horse Artillery gun. Accordingly the H.A. gun is usually the same as the field gun, lightened by removing the axletree seats and using a special light limber containing only about 24 rounds.

In France attempts have been made to lighten the 75 mm. field gun for use with the cavalry by removing the special brake-shoes under the wheels and the gear connected with them, and one Cavalry Division has been equipped with these lightened guns. But the result is considered far from satisfactory, and a lighter gun is desired. Accordingly the French are trying a 70 mm. (2.76″) H.A. gun on the same system as the F.A. gun, but requiring no *abatage*. It is considered that the weight should not exceed 1500 kilos. (29.5 cwt.) behind the team, without gunners; this, with a light limber, leaves about 18 cwt. for the gun, which will be a light 13 pr. similar to the Brazilian Krupp gun. It is to fire only one kind of projectile, namely a combined H.E. and shrapnel shell.

An alternative proposal in France is to introduce a light 75 mm. gun only 25 calibres long to fire the same ammunition as the field gun; but it is difficult to see how such a gun could be kept steady.

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Since the foregoing chapter was printed, the following details regarding the Austrian Gun have been published.

THE AUSTRIAN 1905 Q.F. GUN.

(For many of the details given in this description I am indebted to a pamphlet published by Major Kuehn, Austrian Artillery.—H.A.B.)

This gun is remarkably similar to the Ehrhardt gun. The chief differences between the Austrian gun and the Ehrhardt 15 pr. in our own service are that the gun is of bronze with a wedge breech and that a shield and panorama sight are fitted.

The Gun.

This is of hard-drawn bronze, calibre 3.01 inches, rifled with 30 grooves, twist increasing from 1 in 45 calibres to 1 in 25. The breech action is very similar to the Ehrhardt action illustrated on page 220, but the lever is flattened and extended so as to form a cover protecting the recess in the upper face of the wedge from dust. The firing gear and extractor are the same as those shown on page 220. The gun is fired from the right-hand side.

The sight is an arc sight similar to that on our 15 pr. Q.F. except that the sight-socket is pivoted parallel to the gun-axis and can be cross-levelled. The prolongation of the axis on which the sight pivots passes through the top of the foresight. For all-round laying a panorama sight is fixed on top of the arc sight.

The Cradle.

This is made by Ehrhardt, and is a steel tube of circular section with guides formed on top, along which the gun recoils. It has a vertical trunnion for traversing. This trunnion fits into a recess in a saddle pivoted on horizontal trunnions between the trail brackets; the rearward extension of the saddle forms the traversing bed, as in the German gun.

The Buffer and Springs.

These are contained in the cradle, and are practically identical with those of our 15 pr. Q.F. The buffer is connected to the gun by a horn at the breech-end, and recoils with it. It is of plain construction, with ports and check-buffer; there is no running-up valve or Vavasseur valve. The check-buffer plunger has a small axial hole through which the liquid escapes when running-up. The (single) spring-column consists of 5 springs, right and left-handed, without parting plates. The working length of the column is 74.5″, and it is compressed at full recoil (51.5″) to 23 inches, or less than one-third. This is a higher degree of compression than the German authorities have ventured upon, and is only possible with the best quality of springs, especially since these have to be stout enough to lift the gun at 17° elevation.

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The Traversing Gear is the same as that of the German gun. See page 220. It gives 70 thousandths, or 4 degrees, right and left.

The Elevating Gear is an ordinary double screw, set centrally. The gun has not the independent line of sight.

The Trail is of box pattern, partly open on top. It carries a folding spade of unusual size, namely 8.25″ deep and 32″ wide. When the large spade is turned up there remains a small spade or spur 3.5″ deep which is used on frozen or rocky ground.

The Axletree is straight, with hollow arms.

The Wheels are of wood, slightly dished, plain metal naves. There are 12 spokes, single strut, of which 4 only (those at the junctions of the felloes) have spoke-shoes; the remainder have tongues. The wheel is 4′ 3″ in diameter.

The Brake Gear consists of two brake-blocks on pivoted arms, connected by tension rods with a cross-head in front. It is identical with the Ehrhardt gear on our 15 pr. Q.F.

The Axletree Seats are of sheet steel, perforated for lightness.

The Shield is practically the same as the German shield (page 220). But the top flap does not fold right down, but, when down, projects horizontally to the rear, giving a certain amount of over-head cover. It is 4½ millimetres thick, of special hard steel.

The Limber is much the same as that of our 15 pr. Q.F. It has 12 compartments, of which 11 contain each 3 rounds of fixed ammunition in a carrier. The door opens to the rear, forming a fuze-setting table. There is a large box on the foot-board for stores; kits are carried as on the German limber (page 225). The most remarkable feature about the limber is the spring limber hook; this is on springs which allow it to move vertically, not fore-and-aft as in other equipments. This construction is adopted for the following reasons: The limber hook has to project some distance to the rear, in order to allow sufficient lock with a spade 32″ wide. The weight of the trail therefore exerts considerable leverage, and the play of the trail eye causes a corresponding play of the point of the pole. The spring which is interposed renders the motion of the point of the pole less jerky.—The swingle-trees are attached to spring draught loops.

The Wagon.

The limber is similar to the gun limber. The wagon body is of the high type, having 5 superposed rows of 4 compartments, each containing 3 rounds. The door hangs down to the ground, and there are, besides, two flap doors opening sideways, forming additional shields. The brake is of the South African pattern. The wagon body is unlimbered, not tipped, beside the gun; it has front and rear props. A spare wheel is carried on the perch.

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Detachment.

Three men are carried on the gun limber, two on the axletree seats, and two on the wagon limber. There are no seats on the wagon body, which has a rail at top, and carries stores.

Ammunition.

Fixed ammunition is used; both shrapnel and high-explosive shell are carried. The former is similar to the Ehrhardt shrapnel illustrated on page 61; it contains a 3 oz. driving charge, 316 bullets at 50 to the pound and 16 at 35 to the pound. The fuze is similar to the Ehrhardt fuze (page 69). The high-explosive shell is of the same weight as the shrapnel, namely 14.72 lbs., and ranges the same. It contains 7.5 oz. ammonal, and is fuzed with a T. and P. fuze.

Both shrapnel and H.E. shell have 2-diameter heads; the ballistic coefficient for medium ranges is about 2. Both the shell have a forward copper centreing band as well as the usual driving band. The cartridge case is coned, and is similar to that of our 18 pr.

There is an automatic fuze-key, but no fuze-setting machine.

General Remarks.

This appears to be a simple and serviceable equipment of moderate power. Although fully shielded, the gun weighs only 1 ton in action. Eight numbers, besides the coverer, constitute an unusually strong detachment; the object is presumably to be able to run the gun up to the crest when it is required to support the infantry by direct fire.

THE GERMAN GUN.

The following additional details have now been published:

The gun is styled the M/96 N.A. (*neuer Art.*)

Weight in action ... ... 18.6 cwt.

Weight limbered up ... ... 34 cwt.

The latest pattern shrapnel has 300 bullets of 11 grammes, or 41.3 to the pound.

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MAKERS.

	Krupp.			Schneider.	Skoda.	St. Chamond.	Vickers-Maxim.	
	II.	III.	IV.				I.	II.
Calibre, inches	2.95	2.95	2.95	2.95	2.95	2.95	3.3	2.95
Weight of Shrapne	14.3	14.85	12.1	14.3	14.3	14.3	18	14.33
Number of bullets	295	295	245	294	355	280	364	265
No. of bullets to th	42	41	45	45	49	38	41	41
Muzzle velocity, f.	1640	1640	1600	1640	1640	1640	1620	1706
Muzzle energy, ft.	267	277	215	267	267	267	330	290
Weight of gun, cw	7.37	7.1	6.3	6.67	6.3	6.65	9	8
Weight of gun & ca	21	20.5	16	21.25	20	20.8	24.5	23.5
Weight of gun & li	33.8	37	26.7	35	35.5	35.5	37.5	35.5
Weight of recoili (approximate)	8.6	8.2	7.7	8.84	8	7.85	—	—
Maximum elevati	16	15	17	16	16	17	16	15
Traverse each way	3	3½	3	3	3	2½	4	4
Length of recoil, i	54	54	44	50	50	50*	46	44
Height of wheels	4′ 3¼″	4′ 4″	4′ 3½	4′ 4″	3′ 11½″	4′ 3½′	4′ 8″	4′ 8″
Length of trail, fe	8.66	9	8.1	9	8.25	9*	7	7
Line of sight, wh dependent ..	No	No	No	Yes	No	Yes	Yes	No
Sights, Goniomet scopic, Panoran dinary ..	T.G.	T.G.	T.G.	G	T.G.	P	O.T.P.	O.T.P.
Material of gu Chrome Steel Steel or Bronze	N.S.	N.S.	N.S.	C.S.	N.S.	S	N.S.	N.S.
Length of gun, ca	30	30.5	28	31.4	30	30	28.07	29.7
Breech action, Swinging Bloc centric Screw	W	W	W	S.B.	W	S.B.	S.B.	S.B.
Thickness of shie	0.236	0.236	0.177	0.2	0.163	0.2*	0.125	0.125
Traverse on pivo axle	P	P	P	A	P	A	P	P
No. of rounds in	24	44	32	38	40	36	20	36
,, ,, w	24	48	32	38	40	36	39	36
,, ,, w	64	72	48	72	60	64	40	71
Weight of wagon	35	40	24	36.4	36.2	35	37	35

xtra equipment on limber.

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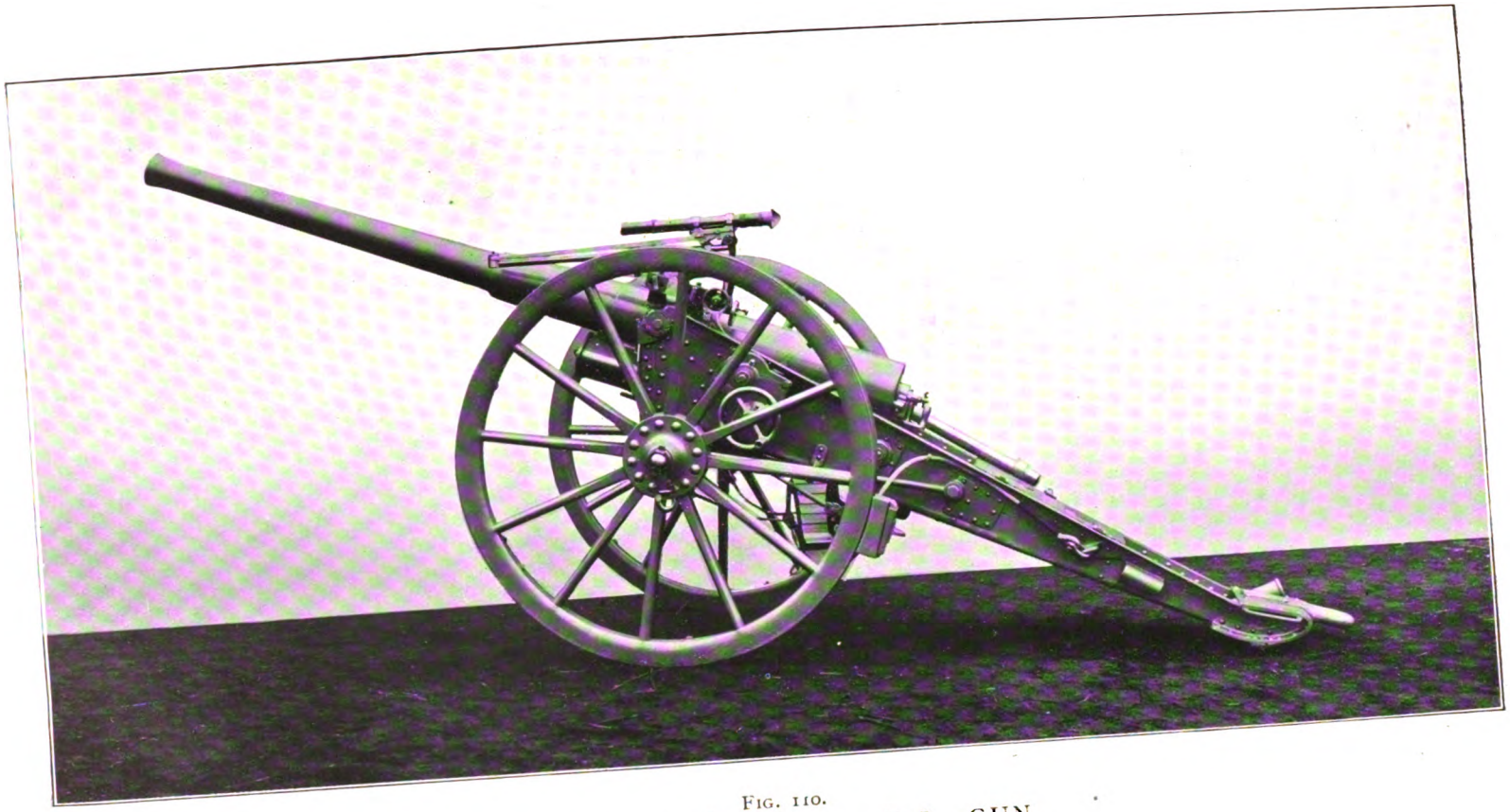

FIG. 110.

"LADY MEUX" 15-PR. B. L. GUN.

1898.

Used by E. O. C. Battery in S. Africa.

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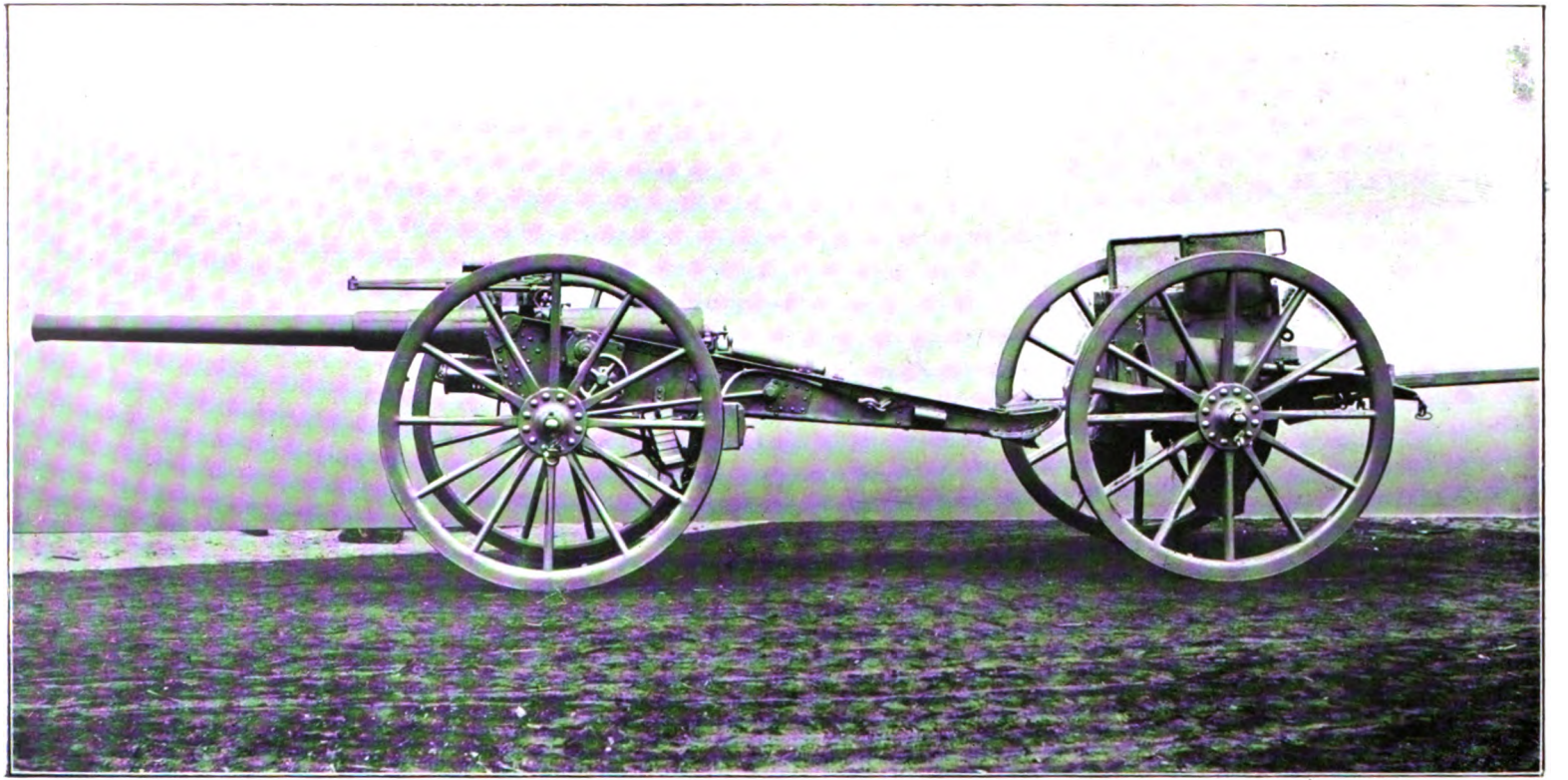

FIG. III.

"LADY MEUX" 15-PR. B. L. GUN.

1898.

Used by E. O. C. Battery in S. Africa.

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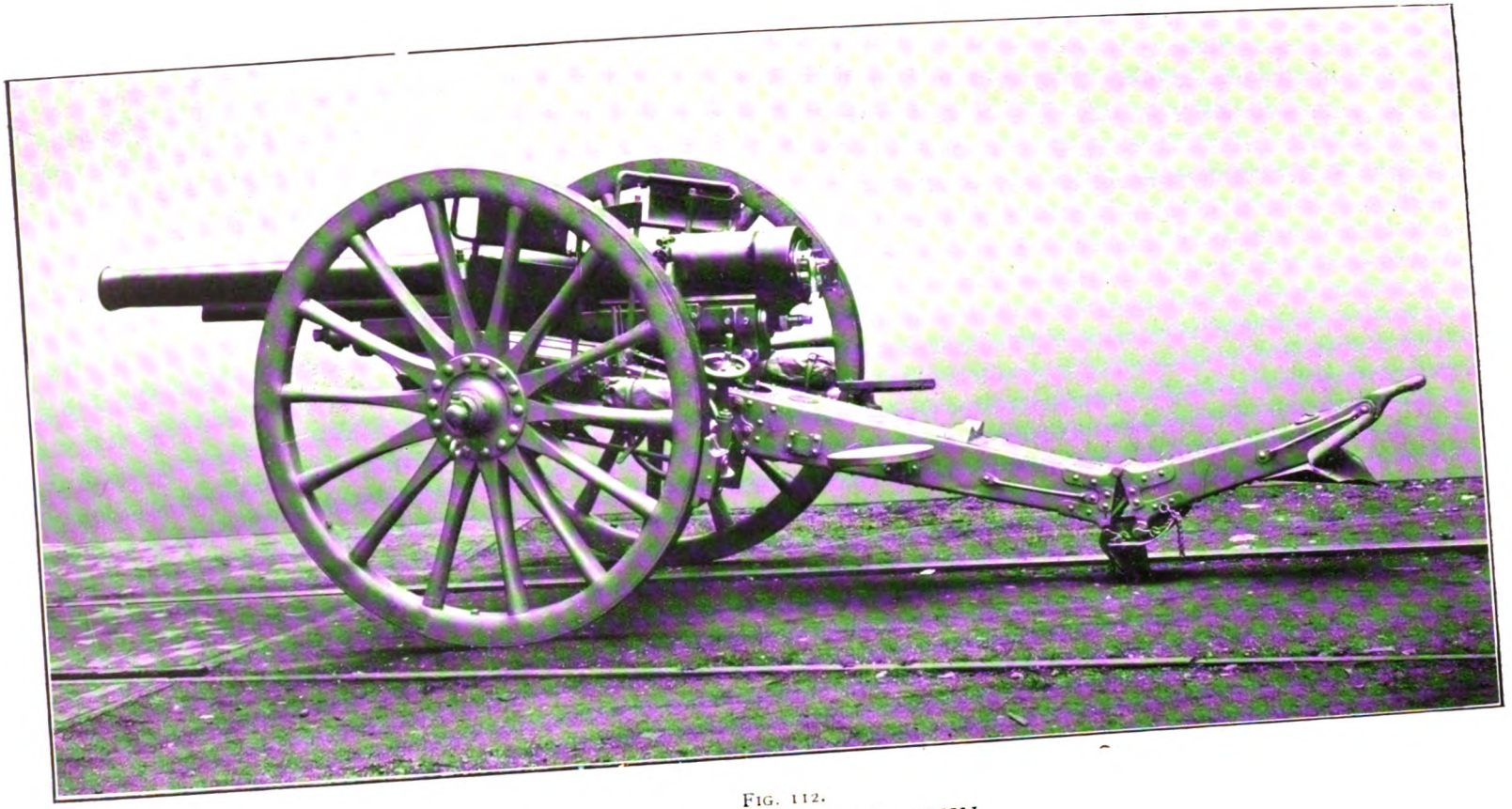

FIG. 112.

ELSWICK 15-PR. Q. F. GUN.

With hinged trail for high angles of elevation.

1897.

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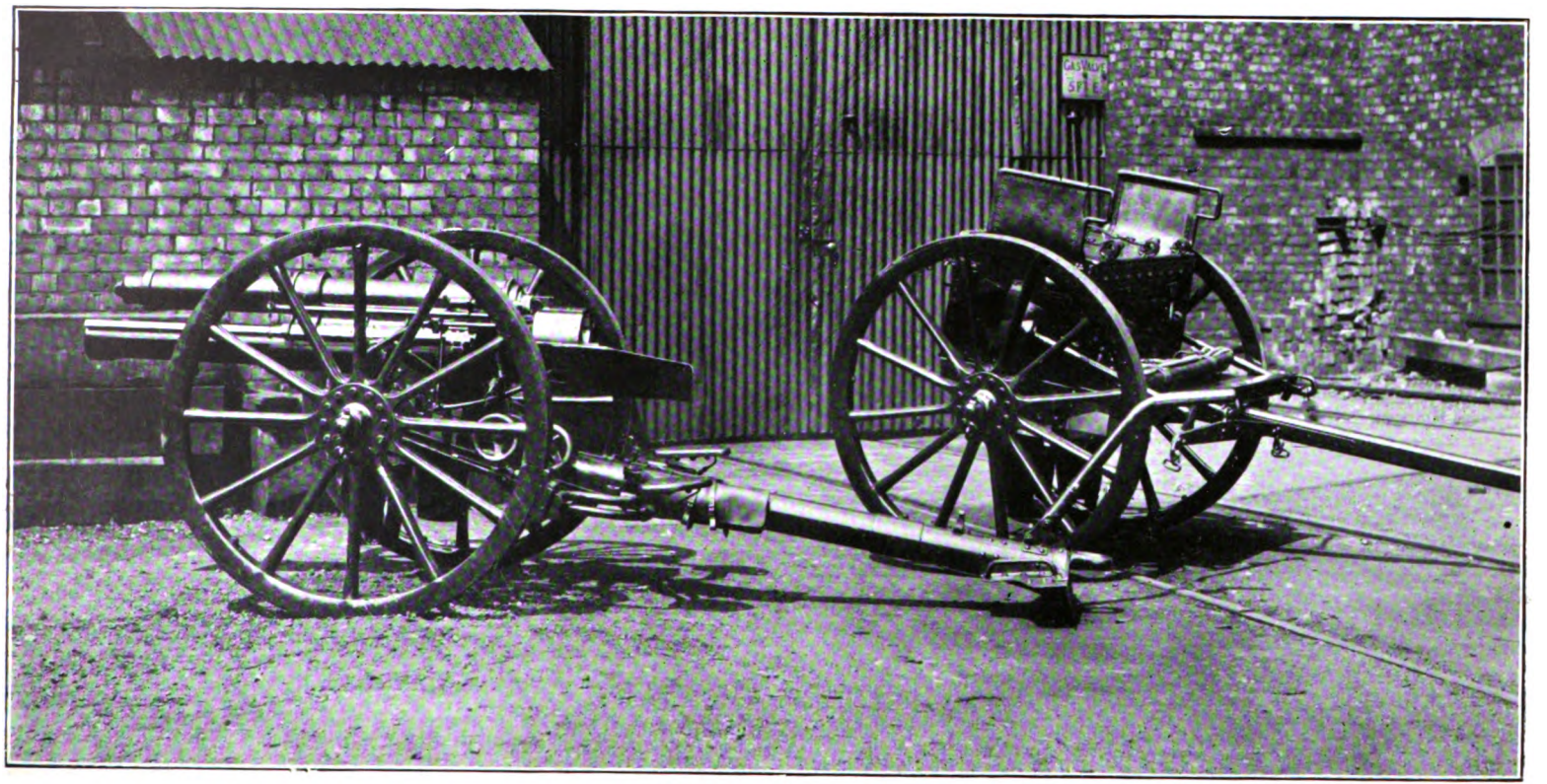

FIG. 113.

ELSWICK 13-PR. Q. F. GUN.

1904.

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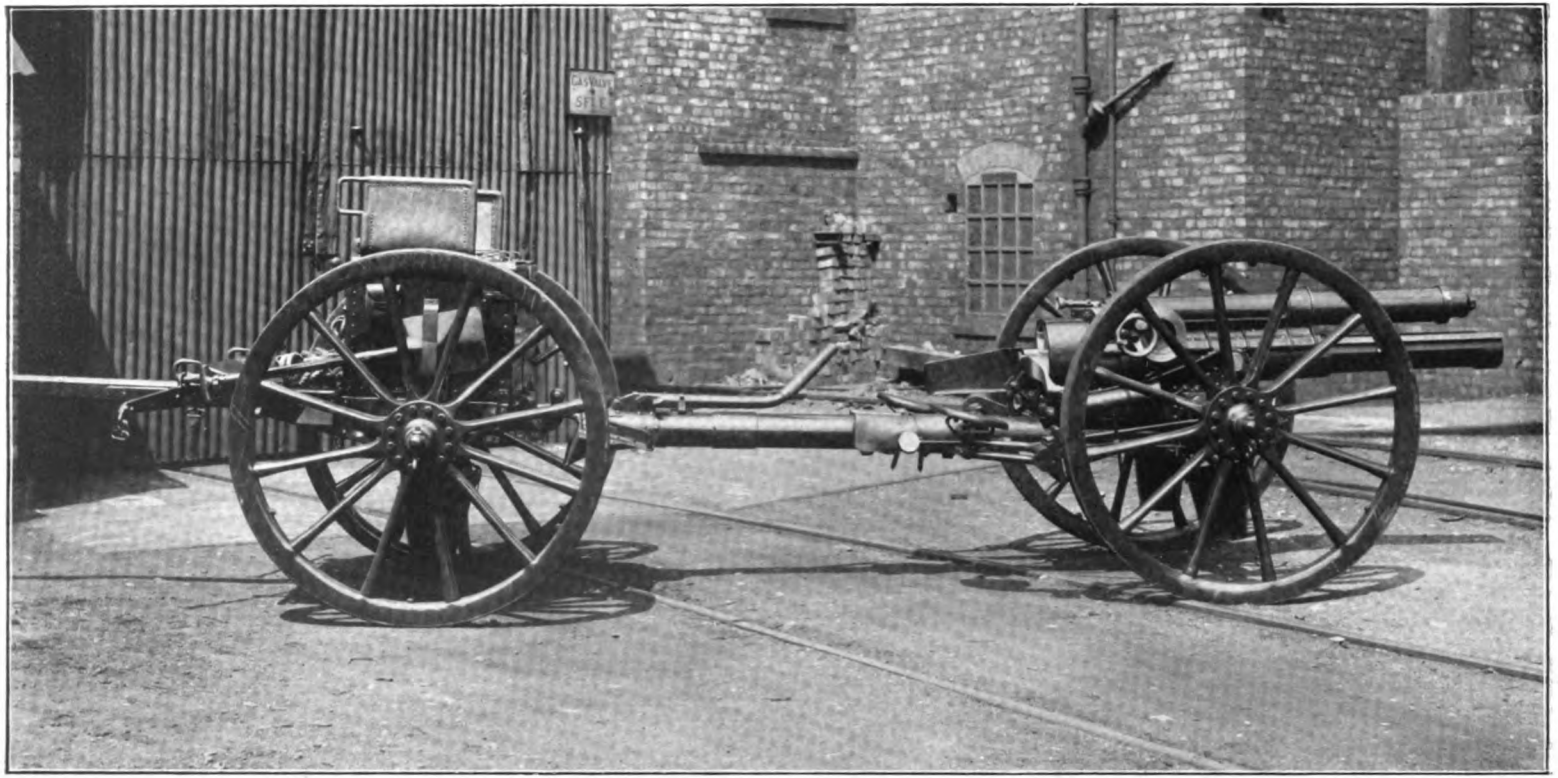

FIG. 114.

ELSWICK 13-PR. Q. F. GUN.

1904.

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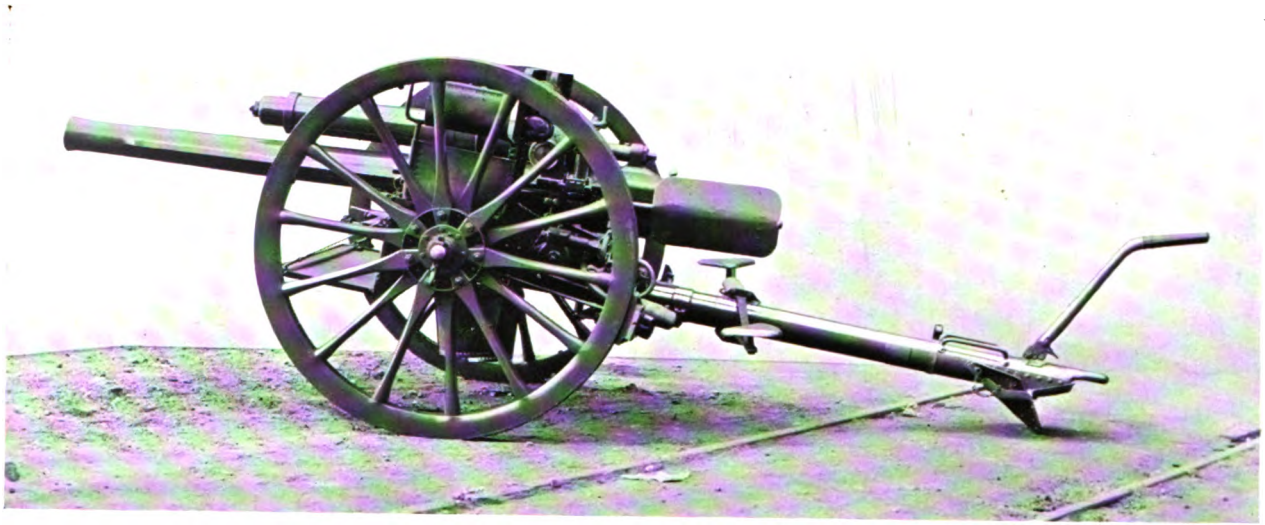

FIG. 115.

ELSWICK 18-PR. Q. F. GUN.

1902.

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CHAPTER XXX.

Q.F. FIELD GUN EQUIPMENTS BY VARIOUS MAKERS.

In this chapter it is proposed only to notice the special features which differentiate the equipments of one firm from that of another.

Details are given in the Table.

1. *Sir W. Armstrong, Whitworth & Co.*

THE ELSWICK ORDNANCE COMPANY.

(Figs. 110 to 115.)

This firm have a 13.2 pr. and a 14.3 pr. equipment. The former is at present under trial in Japan; the latter is the gun shewn at the Milan Exhibition, 1906.

The 13.2 pr. equipment is remarkable for its extreme lightness, the gun weighing only 15.75 cwt. in action without shield. Like all the field guns turned out by this firm, it has a top buffer and telescopic spring-case. The gun is light and comparatively short (28 calibres); the muzzle velocity is obtained by using a large cordite charge, which the wire-wound gun is easily able to withstand. The breech action is the Nordenfeldt eccentric screw. The gun has the independent line of sight and is sighted both for direct and for all-round laying. The elevating gear is the E.O.C. double-ended screw already noticed in the description of the 18 pr. Q.F. gun.

The wagon and limber are shielded and are intended to be placed beside the gun in action. Fixed ammunition of the ordinary type is used, and each round is carried in a separate tube.

The Elswick 1906 14.3 pr. Q.F. Gun.

This gun was exhibited at Milan in 1906. It is an enlarged edition of the 13.2 pr. It is also unusually light; the shielded gun and limber, fully packed, weigh only 32.5 cwt. behind the team.

The gun is wire-wound, and is of Siemens-Martin steel. It has a buffer and telescopic spring-case on top, a ring cradle, and guides on the gun. The elevating gear is the E.O.C. screw as in the light equipment. The gun has the independent line of sight, with a rocking-bar and telescopic sight. A panorama sight can be fitted if desired.

The breech-action is the eccentric screw, as in the French gun.

The gun fires fixed ammunition, shrapnel and H.E. shell. The fuze is double-banked and is partly of aluminium, partly of bronze. The M.V. is 1650 fs.; weight in action 19 cwt. with 3 mm. shield, weight limbered up without gunners 32.5 cwt. only. The latter weight compares favourably with that of the French and German equipments. No axletree seats are fitted, and with three gunners and kits the weight behind the team is only 38.25 cwt.

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The following details are given in addition to those in the Table—

Total length of gun ...	...	7.4 feet.
Rifling, uniform twist.		
Trail angle, 1 in 2.75 or	...	20 degrees.
Charge, cordite ...	...	1.035 lbs.
Remaining velocity at 6200 yards	...	650 fs.
Dimensions of 50% rectangle at 6200 yards	...	Length 22 yards.
	...	Breadth 8.3 yards.
Rounds per minute ...	...	20.

THE BETHLEHEM STEEL COMPANY, PENNSYLVANIA, U.S.A.

(Fig. 116.)

This firm makes a speciality of powerful field guns. Their No. 6 (No. I in the Table) is a 3" gun firing a shell of 15 lbs, M.V. 1700 fs. The makers claim that with 5-millimetre shield it weighs only 19 cwt. in action. Steadiness is ensured by using wheels only 4 feet in diameter.

The gun is 89 inches long, and weighs 6.75 cwt. It has a conical interrupted involute screw breech-block on the Bethlehem system, giving a locking surface extending over 240 degrees of the circle. It has a self-cocking percussion lock, not a trip-lock.

The recoil gear is a Bethlehem specially. There are twin hydraulic buffers under the gun, with the running-up springs inside the buffers. These buffers are nearly as long as the gun. Taking the effective length of the buffers at 80", this means that the springs are compressed from a length of 80" to a length of 35" on recoil. This degree of compression is moderate for good springs.

Several practical advantages are gained by putting the springs inside the buffers. The springs require no parting-plates; they are well lubricated and always work smoothly; and working them in oil instead of in air reduces the vibration and consequently the liability to fracture.

Action of Inside Springs.

The action of springs in a closed vessel filled with oil is deserving of study. When a column of heavy gun-springs, weighing perhaps 1 cwt. with the parting plates, is compressed in air, the action is as follows:—The gun starts to recoil with a velocity of say 30 fs. Owing to the inertia of the springs the column is not compressed simultaneously throughout its whole length. The coils in front, next to the shoulder on the recoiling buffer, are first compressed. Unless, as in some equipments, there is a long collar on the front parting-plate, these coils are compressed metal to metal. The pressure thus exerted on the remainder of the column gradually overcomes its inertia, and a wave of compression passes down the spring. As the gun continues to recoil the spring yields in a series of pulsations, which are very perceptible when sitting on the layer's seat. In running up the reverse action takes place, except that the period of the pulsation is much longer, so that the gun frequently runs up in a series of plainly visible jerks. This shows that the length of the wave (or rather of the dominant wave) is greater than the length of the compressed spring-column.

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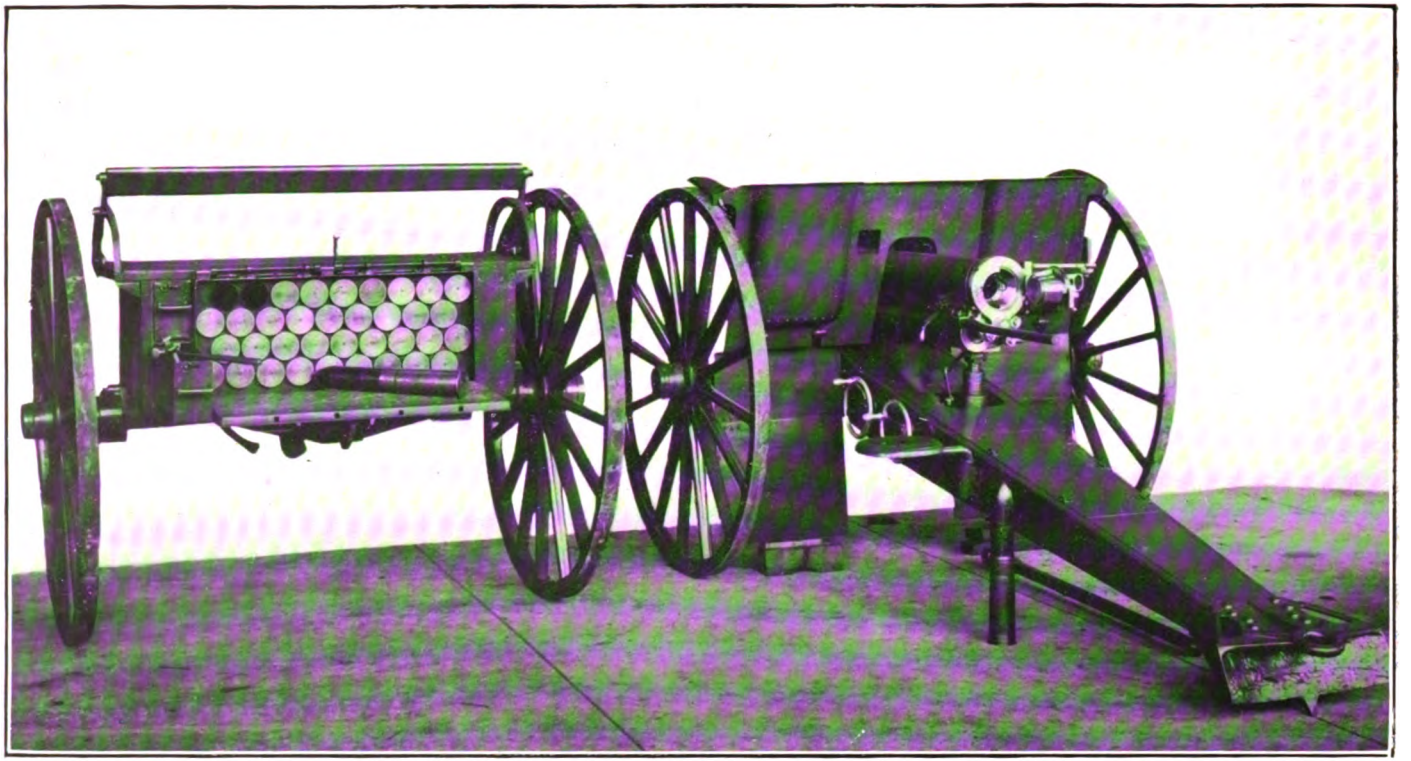

FIG. 116.

BETHLEHEM 3″ Q. F. FIELD GUN.

1906.

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When running-up springs are compressed in a buffer filled with oil or glycerine the pulsations are deadened by the liquid, so that the action is smoother. Besides this, however, there is another point which affects the action of the springs. Suppose the buffer fixed, the piston-rod attached to the gun, and the springs compressed between the piston and the cylinder cover. Then on recoil the liquid next to the piston first escapes, and the coils next to the piston go metal to metal to an extent even more marked than before, since the wave of compression travels down the spring more slowly than in air.

Next suppose the piston-rod attached to the cradle and the buffer recoiling with the gun. Then, owing to the inertia of the spring, the front coils, next to the gland of the buffer, are first compressed. But since the liquid here is stagnant, the effect of the compression is less marked, and the wave passes down the spring before the liquid between the front coils is completely expressed. At the other end of the buffer the coils next to the piston, which is stationary, do not begin to move till the first wave of compression reaches them: they then yield easily, their compression being accelerated by the rush of liquid which is being forced past them. But the wave of compression is weakened by the time it reaches the end of the spring, so that there is here less tendency to crush the coils metal to metal.

The rush of liquid also deadens the return wave which starts back from the stationary end of the spring to meet the next advancing wave of compression. It is probably to the meeting of these two waves that we should ascribe the otherwise unaccountable fractures which sometimes take place, in outside springs, at points at some distance from the ends of the column.

Thus the construction with fixed piston and recoiling buffer with springs inside it assists the spring-column to yield at both ends instead of at the front end only. This materially relieves the stress on the springs.

In a buffer of the Bethlehem construction, in which the cylinder is 50% longer than the recoil-stroke, it would seem possible to allow part of the liquid to escape through a hollow piston-rod through holes near the centre of the spring-column; that is through holes in the part of the rod which does not emerge from the gland. This would allow the spring to yield in three places at once.

Continental makers, such as Krupp and Ehrhardt, who use outside springs endeavour to reduce the inertia of the spring-column by using springs as thin and light as possible. The resistance which the springs have to overcome in running-up is reduced by fitting a running-up valve in the piston. Thus a set of Ehrhart springs for a 75 mm. gun weighs only 24 kilos without the parting-plates.

In the Bethlehem No. 6 field gun equipment the twin buffer-cylinders do not recoil with the gun. Instead of this the two cylinders are connected so as to constitute the cradle, the guides being formed on the upper surface of the cylinders. The gun lies partly between the cylinders, which enables the weight of the gun to be kept low down without the use of a cranked axle.

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The cradle traverses on a vertical pivot set in a socket which is fixed to a sleeve surrounding the axletree, so that the axletree, although it forms the horizontal pivot, does not turn when the gun is elevated.

The trail is of box pattern with a spade inclined at a sharp angle. The elevating gear is of the double screw type. The straight axletree is hollow, with the arms screwed in. The brake-bar is on the muzzle side of the wheels. The gun has ordinary and panorama sights, and is fully shielded.

The Bethlehem gun limbers, wagon limbers, and wagon bodies are all interchangeable. The wagon body has a limber-hook in rear, and the perch is removable so that a pole can be inserted instead. All the ammunition boxes are removable, and any limber can be made into a wagon body by placing a second ammunition box on top of the first, the stancheons fitting into the guard-iron sockets. This interchangeability of equipment is a great advantage.

The Bethlehem No. 5 equipment (No. II in the Table) differs from the last-described in that it is a controlled-recoil equipment. The length of recoil is automatically reduced from 60″ to 50″ as the elevation is increased. This gun has a single buffer with twin spring-columns on either side of it.

Messrs. John Cockerill, Seraing, Belgium.

(Fig. 117.)

The standard field gun made by this firm is a 14.3 pounder, M.V. 1640 fs. It differs in several respects from the ordinary construction.

Between the gun and the cradle is a sleigh; the gun slides on the sleigh, and the sleigh on the cradle. There is a tension spring between the gun and the sleigh, and a compression spring between the sleigh and the cradle. Since the sleigh only recoils for half the distance that the gun recoils, this arrangement serves the same purpose as the telescopic spring-case. It is claimed for these tension springs that it is practically impossible to break them. The sleigh also serves the purpose of supporting the gun in the extreme position of recoil, and thus enables the cradle to be kept much shorter than usual, saving about 1 cwt. of weight.

The recoil and run-up are regulated at all angles of elevation by a stop-cock which automatically constricts the channel through which the buffer-liquid flows. This gear is described in the chapter on Controlled Recoil.

The Cockerill 1905 gun has not the independent line of sight. The makers object to this as it renders it impossible to correct the sight for difference of level of wheels. (This does not apply to the Krupp sight illustrated on page 23, nor to Col. Scott's "Automatic line of sight.") They therefore prefer an arc sight of which the socket is pivoted parallel to the axis of the piece, on Col. Scott's reciprocating system, so that it can be cross-levelled for all round laying. A panorama telescope is mounted on the arc sight.

Another peculiarity of the Cockerill gun is the care taken to protect the working parts both from the enemy's fire and from dirt. Note in the Plate the bellows casing round the elevating screw.

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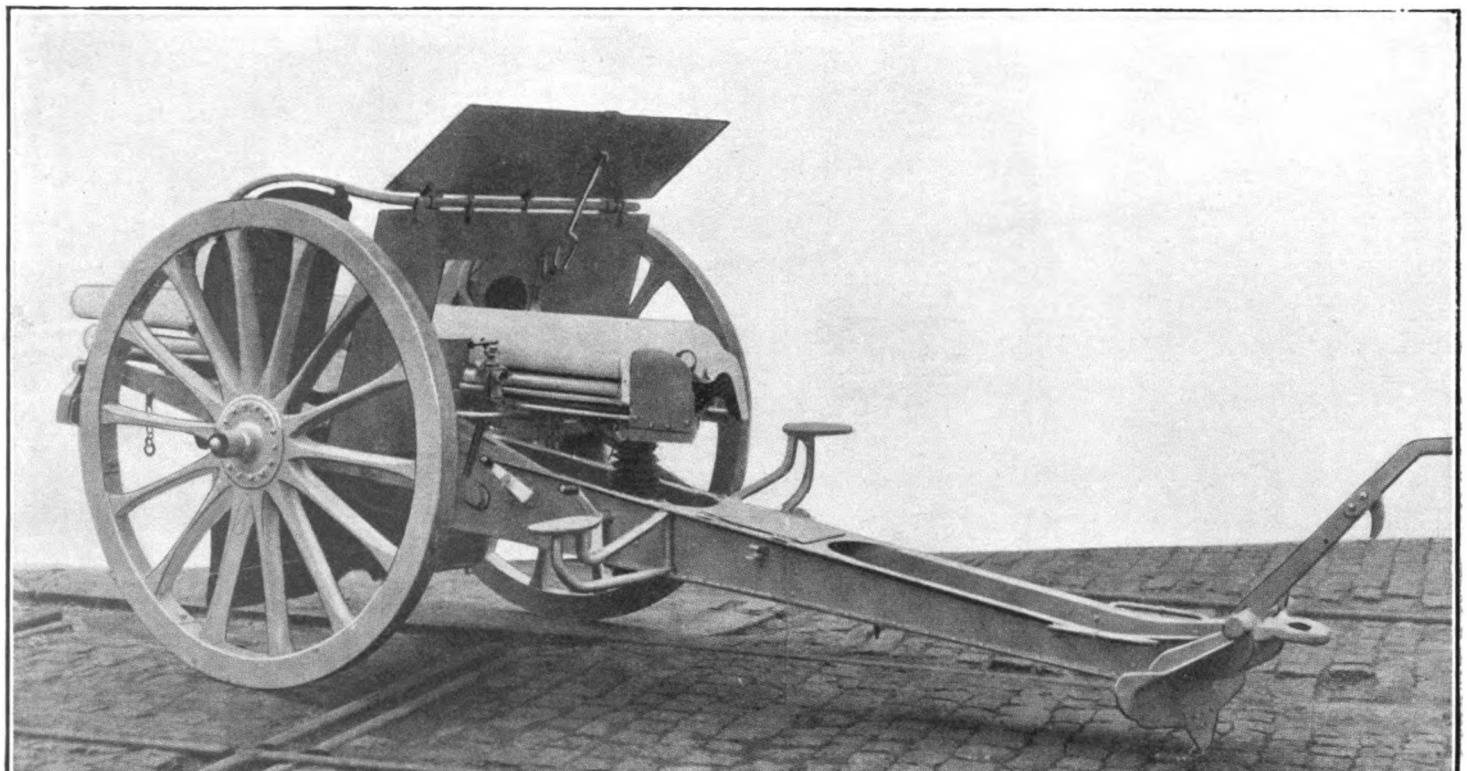

FIG. 117.
COCKERILL 75 mm. Q. F. FIELD GUN.
1905.

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The gun is efficiently shielded. The shield is set far back, and the upper part can be sloped back to give overhead protection to the gunners.

The breech action is the eccentric screw.

The Coventry Ordnance Works.

This is a new firm, an offshoot of Cammell Lairds.

Whereas Elswick go in for lightness, Coventry go in for power and high velocity. Their standard gun fires a 15 lb. shell with M.V. of 550 metres. (1800 fs.)

It has the independent line of sight, and weighs 21 cwt. in action.

The breech action is the Ehrhardt single-motion wedge, which has been adopted for the German gun.

This firm evidently work on the principle of reducing the recoil-energy by putting as much weight as possible into the gun itself. Although their gun is not quite 30 calibres long, its weight is 8.25 cwt., whereas the Ehrhardt No. 1 gun, which is more powerful, weighs only 7.1 cwt. The carriage is comparatively light, weighing only 12.75 cwt., although it has the independent line of sight. It is noticeable that the English makers use comparatively short guns, and get their ballistics by using a large powder charge, whereas the French and German makers get their high velocities by lengthening the gun. Thus the Krupp high-velocity gun is 35 calibres long.

The details of the Coventry gun are given in the Table.

Messrs. Ehrhardt.

(The Rheinische Metallwaaren und Maschinenfabrik, Duesseldorf, Rhenish Prussia.)

Fig. 118.

It is only necessary to give a brief description of the equipments of this firm, since their 1900 gun is described in full detail in the Handbook of the 15 pr. Q.F. gun.

The gun is of nickel steel, from 30 to 31 calibres long. It is in two layers, each formed by forcing a plunger into a red-hot ingot of steel. Messrs. Ehrhardt use by preference their own single-motion wedge breech action, which has been adopted for the new German gun; but they also fit the Nordenfeldt eccentric screw and the ogival swinging block. The Ehrhardt wedge is illustrated on page 220. It is an unusually powerful action. It has a repeating trip-lock fired by a firing-lanyard on the right side of the cradle. The gun is rifled with a twist increasing from 1 in 50 to 1 in 25 calibres, and is sighted on the cradle with arc and panorama sights.

The Ehrhardt gun recoils upon a cradle containing the buffer and running-up springs. In the original equipment three concentric columns of springs were used, but since the adoption of the running-up valve already described these have been replaced by a single column of light springs. The initial compression is given to these springs by an inner sleeve with a shoulder against which the springs abut; this sleeve, which is about 2 feet long, is screwed on to the buffer cylinder, which is threaded to receive it, till the necessary compression is obtained. This enables the springs to be quickly removed and replaced.

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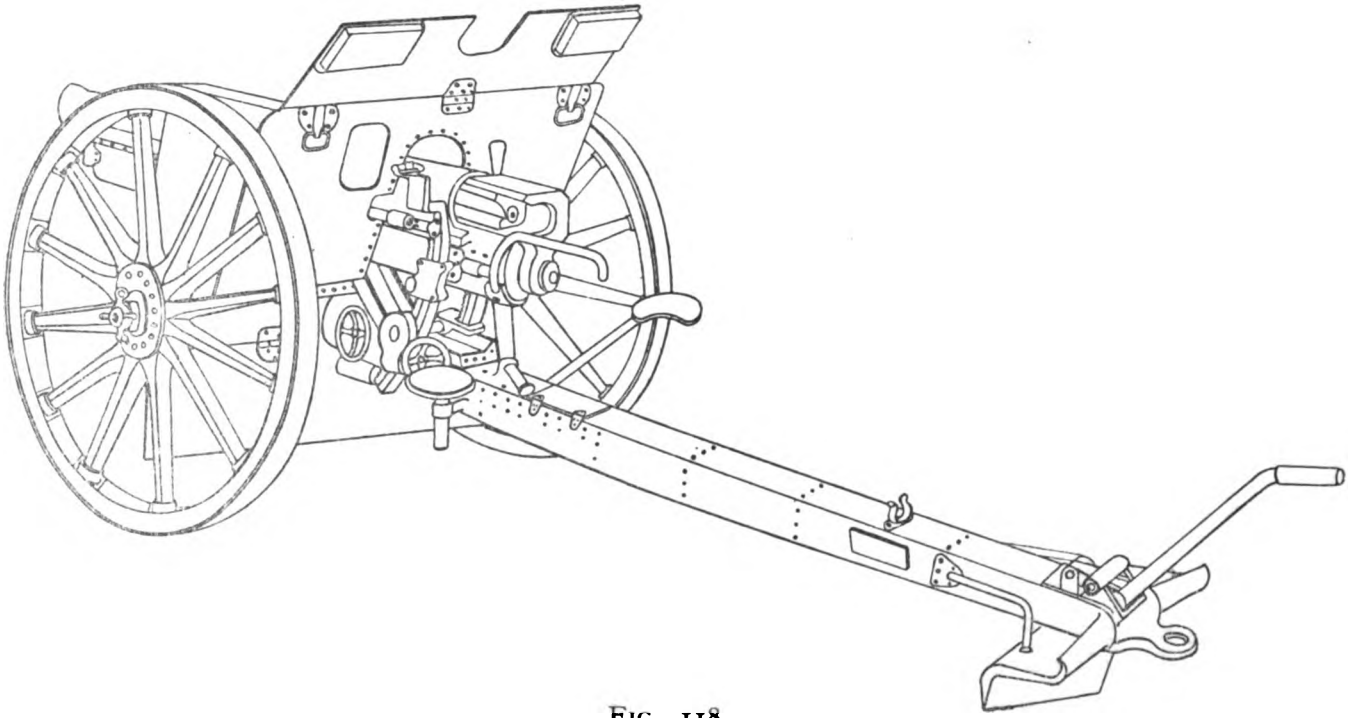

FIG. 118.

EHRHARDT 75 mm. Q.F. GUN.

With Independent Line of Sight.

1906.

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The buffer is now attached by a horn to the breech of the gun and recoils with it. The cradle is a drawn tube of closed U section, the upper edges forming guides upon which the gun recoils. The cradle has a vertical trunnion set in a socket in the axletree; when the gun is elevated the axletree turns with it. Under the breech end of the cradle is the traversing plate, which is attached by stays to the shoulders of the axletree, forming a light and rigid construction. The elevating gear is of the double screw type, set centrally in the trail. The trail is a drawn tube of closed U section, specially designed for stiffness in a vertical plane. The old telescopic trail has been abandoned. The original Ehrhardt trail was 10′ 6″ long, but improved buffer-boring has enabled the length to be reduced to 9 feet while still maintaining perfect steadiness. The trail is connected by capsquares to the axletree, so as to allow the latter to revolve when the gun is elevated or depressed. The spade is of the form shown in Fig. 118; it is inclined at an angle of 18° to the vertical.

Messrs. Ehrhardt have also an equipment with independent line of sight, which presents several original features.

The cradle is pivoted on horizontal trunnions on an intermediate carriage, which itself traverses on a vertical pivot set in a sleeve on the axletree, which does not revolve. There are twin double-ended elevating arcs. By turning a laying wheel on the intermediate carriage the arcs, gun, and sights are elevating together; by turning an elevating wheel on the cradle the gun moves up or down the arcs without moving the sights. So far the principle is the same as that of the E.O.C. double-ended elevating screw gear. But in the Ehrhardt gear the arcs themselves are utilized as arc sights, being struck with the cradle-trunnion as centre, and the panorama sight is mounted directly on top of the left-hand arc. The clinometer level is fixed to the side of the same arc.

For direct laying a rocking-bar sight is used as an alternative to the panorama telescope. The rocking-bar is an integral portion of the left-hand arc; it passes through the axis of the cradle trunnions and is continued to the front so as to give a sighting radius of 1 metre. The foresight is capable of lateral movement, and is governed by a cam on the side of the cradle, which moves it to the right as the gun is elevated. This gives the true correction for drift at all angles of elevation.

The Ehrhardt 1907 gear differs from that just described in that the arcs are single-ended. They are continued downwards only as far as the intermediate carriage, to which they are fixed. The intermediate carriage is elevated and depressed by the laying screw, which is a central screw of the ordinary pattern.

The Ehrhardt double-strutted steel wheel is shown in Fig. 35. Steel wheels have been extensively tried, but are considered to cause excessive vibration in travelling, and a wooden wheel is generally preferred.

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Ehrhardt Ammunition.

Messrs. Ehrhardt are very successful makers of ammunition, and claim to get a higher percentage of bullets and driving charge into a field shrapnel than any other firm. They draw their cartridge cases hot. All their shrapnel bodies are solid-drawn, and are made by forcing a plunger into a hot ingot, which is then drawn out by passing it through three successive sets of dies. Another Ehrhardt speciality is their method of rolling in the incurved shoulders of the shrapnel bodies instead of pressing them in.

The Ehrhardt ammunition and fuzes have been described in Chapter IX.

The Ehrhardt 1907 high-explosive sharpnel differs slightly from that illustrated on page 66. The H.E. burster now forms a portion of the fuze, instead of being set among the bullets. The bullet capacity is 47% as before.

Messrs. F. Krupp, Essen, Rhenish Prussia.

(Figs. 103 and 104.)

The Krupp field gun equipments have already been fully described, and it is unnecessary to go into further detail, except as regards their new high velocity gun. No less than eight States have purchased Q.E. equipments from Krupp. These equipments are all of moderate power, and do not attempt to rival the ballistics of the English, French, or Russian guns.

None of the Krupp guns, large or small, are wire-wound.

The Krupp equipments are all of strong and simple construction, and the complications entailed by compressed-air gear and telescopic spring-cases are avoided.

The following points are common to all the Krupp field gun equipments:—

(*a*) Single-motion wedge breech.

(*b*) Cradle pivoted on a saddle between the trail brackets.

(*c*) Box trail bent to give room for the elevating gear.

(*d*) Recoil regulated by buffer-ports, run-up regulated by a spring running-up valve and Vavasseur cut-off valve. No check-buffer.

(*e*) Single column of running-up springs.

(*f*) Compressor screw for putting initial compression on springs.

(*g*) Spade with ground-plates extending to front and rear.

The Krupp wagons are shielded, and are of either the French or the non-tipping type. Each round is carried in a separate tube. There is no fuze-setting machine, but an automatic fuze-key is provided.

The Krupp ammunition is of well-known excellence. Their field shrapnel all contain 50% of bullets besides a large driving charge and smoke-producer. The Krupp fuze has been adopted for the English field guns.

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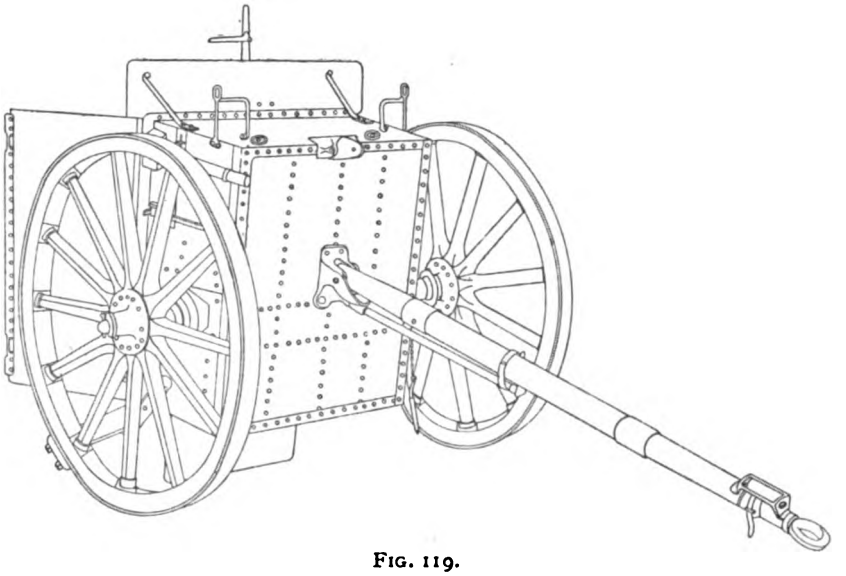

FIG. 119.
KRUPP WAGON BODY.

The Krupp High-Velocity Field-Gun (1906).

This gun is of 71 mm. (2.795″) calibre and fires a 14 lb. combined shrapnel and high-explosive shell, with a M.V. stated at 610 metres (2000 fs.) This gun has a semi-automatic breech mechanism; this is similar to that of the Krupp mountain gun except that the wedge is set vertically; the breech is open at top instead of at the side, which is more convenient for rapid loading. The gun has an intermediate carriage and has the independent line of sight. It is 35 calibres long, and has the Krupp recoil gear. The trail is longer than usual, namely 10 feet; the wheels are 4′ 3½″ in diameter, and the brake blocks are on the muzzle side of the wheels.

The laying, elevating, and sighting arrangements are all on the right-hand side of the breech. This is in order to give plenty of room for the two loading numbers to work in, so that they can keep pace with the high rate of fire allowed by the semi-automatic breech action. The gun is stated to be easily capable of 30 rounds per minute.

Full particulars of this equipment have not yet appeared. The details, so far as known, are given in the Table. The weight in action is probably about 22.5 cwt. with 4 mm. shield.

This gun is undoubtedly the most powerful field gun which has yet been produced.

Messrs. Schneider, Canet & Co., Le Creusôt, France.

The standard field gun equipment of this firm has been described under the heading of the Portuguese Q.F. Gun. The following points are common to Messrs. Schneider's field gun equipments:—

Use of chrome steel.	All-round sights.
Gun about 32 calibres long.	Compressed air running-up gear.
Interrupted screw breech action.	Traverse on axletree.
Independent line of sight.	Box trail.

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The Schneider guns are remarkably steady in action. This is due partly to the fact that the recoil-energy is reduced by making the whole of the recoil gear and running-up gear recoil with the gun, except the pistons; partly to the smooth action of the compressed-air gear.

The wagon is tipped beside the gun as in the French equipment, and is provided with an automatic fuze-setting machine.

Both gun and wagon are fully shielded.

The Skoda Ordnance Factory, Pilsen, Bohemia.

(Figs. 120 and 121.)

The standard gun made by this firm is a 75 mm. 14.3 pounder, M.V. 1640 fs. The gun is of nickel steel, 30 calibres long.

It is rifled with increasing twist, and has the Skoda single-motion wedge breech. This action is closed and locked by a knuckle-jointed lever, and is a simple and very serviceable gear. It has a repeating trip-lock and firing-lever. The extractor is actuated by a projection on the wedge which strikes a bent lever when the breech is opened.

The gun has an arc sight, which is pivoted so that it can be cross-levelled to correct for difference of level of wheels. It is inclined to correct for drift. The arc sight carries a base-plate and divided circle with sighting telescope for direct or all-round laying. The telescope, which also carries open sights, can be raised above the base-plate by means of a pillar when an extra high line of sight is required. A panorama sight can also be fitted on the base-plate.

The clinometer, which is adjustable for angle of sight, is carried low down on the side of the arc sight.

The cradle is cylindrical, and contains the guides as well as the buffer and springs. A steel forging inside the cradle slides backwards and forwards on these inside guides, and the gun is supported on this by connecting-pieces which pass through a slit in the upper surface of the cradle. The cradle only extends forward to 2/3 of the length of the gun; on the other hand, it projects about one foot in rear of the breech. The object of this is to keep the working parts behind the shield and to support the gun at extreme recoil. The spring case is telescopic. A spare set of springs and spring-case, with the initial compression already on, is carried in the hollow perch of the wagon.

The gun fires fixed ammunition, both shrapnel shell and H.E. shell loaded with ammonal. The ammunition is carried by fours in steel boxes. The wagon body is unlimbered beside the gun in action, but is not tipped; the perch is supported by a prop. The gun and wagon are fully shielded; the gun-shield has a folding top like that of the German guns.

This equipment has unusually low wheels, namely 3′ 11½″.

It is said to be a strong serviceable equipment, perfectly steady in firing. But its weight seems rather high with regard to its power and to the size of the wheels. With 3 mm. shield it weighs 20 cwt. in action, and with a 4½ mm. shield, which is now considered necessary, it would weigh nearly 21 cwt.

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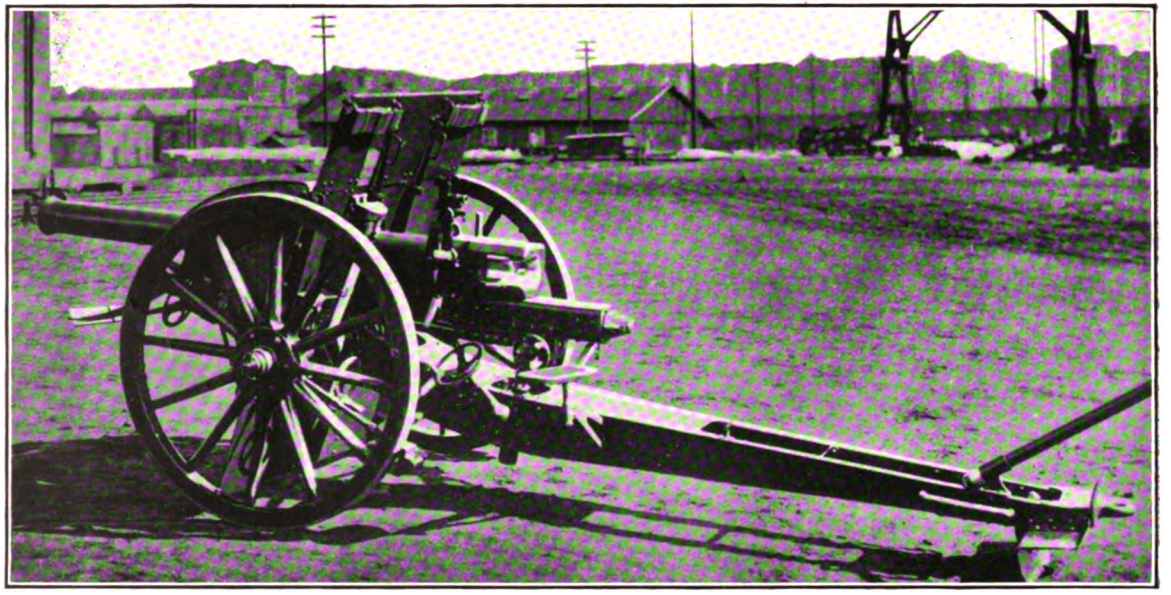

FIG. 120.

SKODA 75 mm. Q. F. GUN.

1905.

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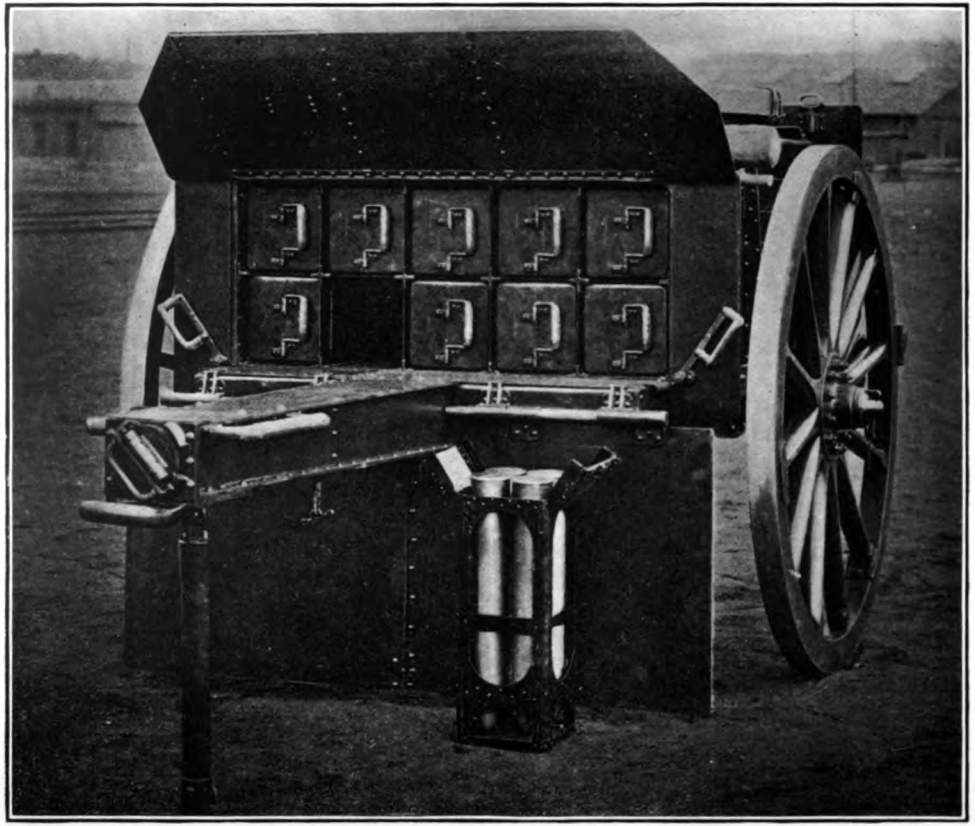

FIG. 121.

SKODA WAGON BODY.

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The St. Chamond Steel Company, Loire, France.

(See Fig. 108.)

The standard gun made by this firm is a 75 mm. 14.3 pounder, M.V. 1640 fs.

The gun is of special steel, 30 calibres long. It has an interrupted screw breech-block with repeating trip-lock. It is sighted on the cradle with a panorama sight, and has the independent line of sight. The gun is mounted on a sleigh of which the transverse section is the arc of a circle. This sleigh rides on the cylindrical cradle. The cradle contains the buffer and single column of springs. The buffer recoils with the gun; it is of the ordinary construction, with check-buffer. The gun traverses on the axletree; it requires no *abatage.*

The limber and wagon are remarkable in that all the ammunition boxes are on springs, and that spring draught-loops and spring limber-hooks are fitted. The (fixed) ammunition is carried vertically. The wagon body is tipped beside the gun in action, and has an automatic fuze-setting machine.

The gun fires 25 rounds a minute, and the sights and elevating and traversing gear are specially designed for fire from behind cover and for searching and sweeping. Both gun and wagon are fully shielded.

Messrs. Vickers Sons & Maxim, Sheffield.

This firm have two standard gun equipments.

The heavy equipment is similar to the 18 pr. Q.F. in power. The construction is much the same as that of the 18 pr.; the principal difference is that twin telescopic spring-cases on either side of the buffer are used. This enables the buffer and springs to be got closer to the gun and gives a more compact construction than the column of springs surrounding the buffer.

The carriage differs from that of the 18 pr. in that an intermediate carriage on horizontal trunnions is used, so that there are two elevating screws, one for the intermediate carriage and sights, the other for the gun itself. Messrs. V. M. prefer this construction to the double-ended elevating screw, as it enables the screws to be directly under the gun.

The gun is sighted on the intermediate carriage with a rocking-bar sight carrying a telescope for laying and a panorama sight. The breech action is the Vickers-Maxim swinging block, which has been adopted for the Q.F. field guns in our service.

The Vickers-Maxim Light Equipment is a high velocity 14.3 pounder. This gun was exhibited at Milan in 1906. It is similar in its general features to the German makers' equipments, but is intermediate in power between their "ordinary" and their high-velocity guns. It has not the independent line of sight.

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THE KRUPP VERSUS SCHNEIDER COMPETITION.

In January, 1904, the Portuguese Government tried a Krupp field gun against a gun by Schneider of Creusôt. The report of the Committee is of great interest.

Both guns fired a shrapnel of 14.3 lbs. with M.V. of 1640 fs. The Krupp gun weighed 19.5 cwt. in action, the Schneider 21.1 cwt. or 1.6 cwt. more. The Schneider only weighed 35 cwt. limbered up as against 36.5 for the Krupp, but it carried 6 rounds less, and its wheels were considered too light for Portuguese roads. With wheels similar to the Krupp, and with a limber fitted to carry 6 more rounds, the Schneider would have weighed about 38 cwt. limbered up. The supply in the Schneider limber was however considered sufficient, as the Schneider wagon body carried 8 more rounds than the Krupp.

The Schneider gun had a plain buffer, with no piston-valves; it had the compressed air running-up gear, separate from the recoil gear. The run-up was regulated by a check buffer. The Krupp gun had a buffer with ports for regulating recoil and with spring running-up gear regulated by a spring running-up valve and Vavasseur valve in the piston.

The Schneider gun traversed along the axle, the Krupp on a vertical pivot.

The Schneider gun had the independent line of sight, the Krupp had not.

The Schneider gun had interrupted screw breech mechanism, the Krupp had the wedge.

The Schneider shrapnel contained 290 bullets of 45 to the pound as against 360 of 51 to the pound for the Krupp shrapnel.

The Committee found that the Schneider recoil gear worked more smoothly than the Krupp gear, and that the gun was steadier. This was ascribed partly to the extra weight of the Schneider.

The buffers of both gun worked well. The compressed-air running-up gear never failed to return the gun to the firing position, even when the trail was sunk to allow of 28° of elevation being given, whereas the Krupp springs become weaker after long firing, and had to be assisted by hand at 14° elevation and over.

There was absolutely no loss of air from the Schneider in travelling or firing, but after prolonged firing it lost a small quantity of glycerine. It was estimated that this loss would amount to one litre after about 2000 rounds. This would reduce the pressure to 19 atmospheres, which pressure would still suffice to run the gun up at 20° elevation. The glycerine was replaced by pumping in an equivalent quantity. Time under 5 minutes.

The Krupp gun broke two springs—or, according to another account, it broke the same spring twice. On each occasion $\frac{3}{4}$ of a turn broke off the end of the spring. The gun continued to run up correctly with the broken spring. Time taken to replace spring, about 5 minutes.

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The breech mechanism and traversing gear of the two guns worked well.

The Schneider goniometric sight, with independent line of sight, was considered much superior to the Krupp arc sight and laying plane; the Schneider sights were altogether better adapted for laying behind cover than the Krupp sights, as also for searching and sweeping.

As regards accuracy and rapidity of fire there was little to choose between the two guns.

The Committee considered the Schneider shrapnel bullets of 45 to the pound more effective than the Krupp bullets of 51 to the pound; but this point does not effect the merits of the guns.

The Schneider fuze was somewhat more regular than the Krupp fuze. But it appears from the report that the number of rounds on which the error was calculated was not sufficient to afford reliable comparative results.

The Schneider fuze-punching machine was much approved of and was preferred to the Krupp fuze-setter.

The principal reasons assigned by the Committee for preferring the Schneider gun were :—

(*a*) That the Schneider sights and laying gear were superior to the Krupp.

(*b*) That the compressed air running-up gear was more serviceable than the springs. For the Krupp springs were considered to be strained nearly to their elastic limit, and would require frequent renewals; whereas spare glycerine was easier to carry in the field than spare springs.

The President of the Committee dissented from the above opinion and reported in favour of the Krupp gun, principally on the ground of its lesser weight and greater simplicity. He considered the Krupp gun to be the stronger and more serviceable of the two.

The Minister for War, having duly considered the reasons given by the President for his dissent, supported the opinion of the majority of the Committee, and the order for guns was accordingly given to Schneider.

Spain followed suit a few months later by ordering her new field equipment from the same firm.

The Schneider equipment has been freely criticised by Col. Nunez, the President of the Committee, and by other advocates of the Krupp system.

The following are the principal objections made to it by these critics :—

1. The Schneider has two packed glands and one packed piston, instead of one gland as in the Krupp system. It is doubtful whether these packings can be kept tight on service, and it is very probable that if the gun is kept for any time in ordnance store the packings will suffer, even if the air pressure is let down. And if any one of these packings is out of order, this puts the gun out of action.

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(It may be here noted that our own experience with hydraulic jacks is that the best way to keep the packings tight is to keep the jacks under pressure.)

2. Besides the glands and piston there are four screwed-on covers and an inlet valve and plug which have to be kept tight.

3. The check-buffer plunger is long and slender and liable to break.

4. The cradle guides and slides are very short. To support the gun at full recoil there are two projections on the gun near the muzzle which engage with the cradle guides on recoil. The slightesf damage to these projections or to the guide will put the gun out ot action.

5. The axle-traversing gear is heavy to work and liable to jam.

6. The firing mechanism is a swinging hammer which is made to strike the firing-pin by jerking the lanyard. This is inferior to the Krupp spring repeating-lock. Moreover if the lanyard be jerked while the breech is imperfectly closed the hammer strikes the breech-fittings and damages them, causing jams.

7. The fact that the Schneider gun is steadier than the Krupp is entirely due to its excessive weight (21.25 cwt.) and excessive trail lift (1.72 cwt.) which render it unhandy.

8. The whole equipment, in spite of its weight, is weak, especially as regards the wheels, and unfit for hard service. The 300-mile travelling trial carried out by the Portuguese Committee was insufficient to test it thoroughly.

9. The axletree seats were added as an after-thought; they are mere perches, too small to be of any use.

10. The shield-protection is inferior to that given by the Krupp shield. The latter is ½mm. thicker and has a hood which closes the aperture around the gun.

11. The Portuguese Committee claimed that the compressed-air gear was superior to the springs because the latter were so severely compressed on recoil as to crush and weaken them. The Krupp advocates contend that the springs are fully up to their work, and that experience with the Krupp guns supplied to 8 different States shows that the springs are fully reliable.

(It may be noted that the Germans, in their new equipment, have taken care to be on the safe side. The springs are only compressed to about half their working length, instead of to one-third as in most Krupp equipments.)

12. The Portuguese Committee stated that the compressed-air gun always ran up properly, whereas the Krupp failed to run up completely at high elevations. The President of the Committee, in explaining his dissenting vote, states that the Krupp only failed to run up by a fraction of an inch, and that this in no way affected the action of the mechanism.

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These objections to the compressed-air gun may or may not be well founded. Similar objections were made to the complications of the breech-loading rifle, but it has survived them. A couple of year's wear, which the guns have now had, should enable the Portuguese to decide whether their equipment is sound and fit for war. The only collateral evidence on this point is the experience of the French with their hydropneumatic equipment. The French gun was issued in 1899, and, so far as can be learnt, has stood its eight years of travelling and firing remarkably well.

From a scientific point of view it is unfortunate that practically all the fighting nations have re-armed, so that there is no present prospect of another competitive trial between the two systems as applied to field guns. But it is possible that the contest between springs and compressed-air may be renewed over the design of the heavy field guns, mountain guns, field howitzers, and mountain howitzers which all nations now consider essential to complete their armament.

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CHAPTER XXXI.

SOME MODERN Q.F. FIELD HOWITZER EQUIPMENTS.

The Ehrhardt 4.2″ Q.F. Field Howitzer (1905).

FIG. 122.

This is similar in general construction to the Ehrhardt Q.F. field gun. It has the device already described for reducing the gun-recoil at high angles of elevation, and a quick-motion elevating gear to bring the howitzer to the loading position. The elevating gear is a long arc fixed at both ends to the cradle. The breech action is the single-motion wedge. The howitzer is mounted on an intermediate carriage, and has the independent line of sight. The recoil is 56″ point-blank and 32″ at full elevation; this keeps the carriage steady at any elevation. Messrs. Ehrhardt fit either a 3.5 mm. shield, bullet-proof at 330 yards, or a 5 mm. shield, bullet-proof at 110 yards. Case ammunition is used.

The details are as follows—

Calibre	...	...	4.2 in.
Muzzle velocity	...	...	986 fs.
Weight of shell	...	...	30.8 lbs.
Weight of howitzer	...	...	7 cwt.
Weight in action with shield		...	22 cwt.

Messrs. Ehrhardt have also a 4.7″ howitzer of similar construction.

The Krupp 4.7″ Q.F. Field Howitzer (1902-03).

FIGS. 123 and 124.

(See also illustration opposite page 75.)

This howitzer has a long open trail, a buffer under the gun, and two sets of running-up springs, one on each side. These springs are not enclosed in cases, but are exposed. This arrangement diminishes friction and prevents the chance of a spring being jammed by a bullet striking the spring-case. The elevating gear is of the arc type; the breech action is the Krupp wedge, and the howitzer has an all-round pedestal sight mounted on a long arc. There is an arrangement for illuminating the sights for night firing. The charge is contained in a brass case, and consists of five charges of smokeless powder, enclosed in bags of gun-cotton cloth, and numbered from 1 to 5.

No. 5 charge consists of all five bags; to make No. 4 charge, take out the top bag, when the figure 4 is seen on the next bag; to make No. 3 charge, take out another bag, and so on. The bags are not of equal weight, but contain respectively 205, 40, 60, 75, and 110 grammes of powder.

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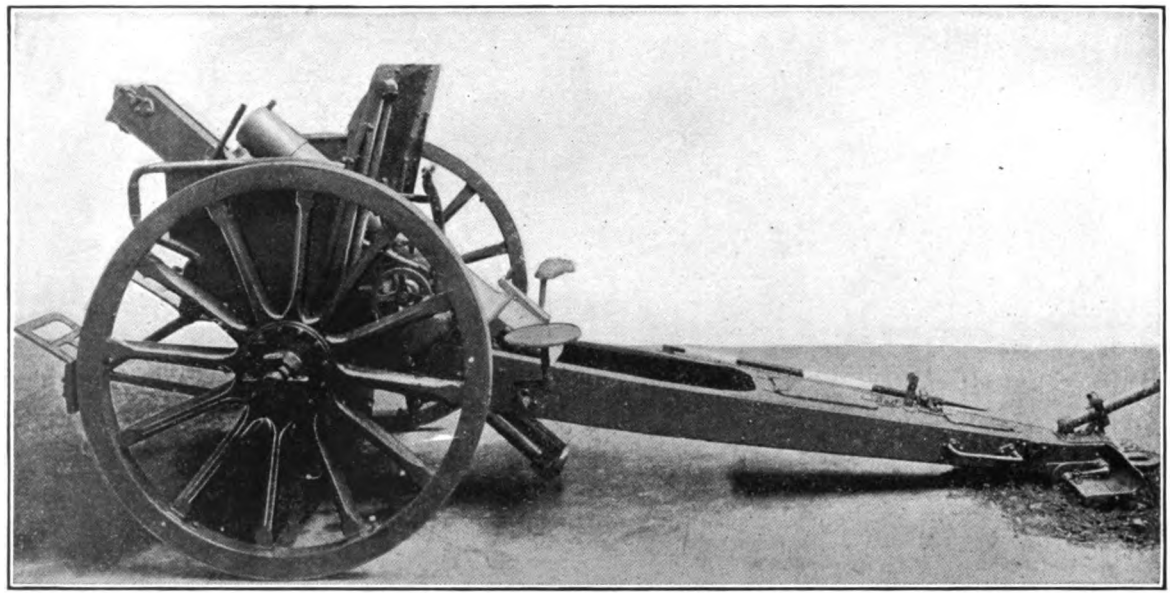

FIG 122.

EHRHARDT 4.2″ Q. F. HOWITZER.

(Recoil position.)

1905.

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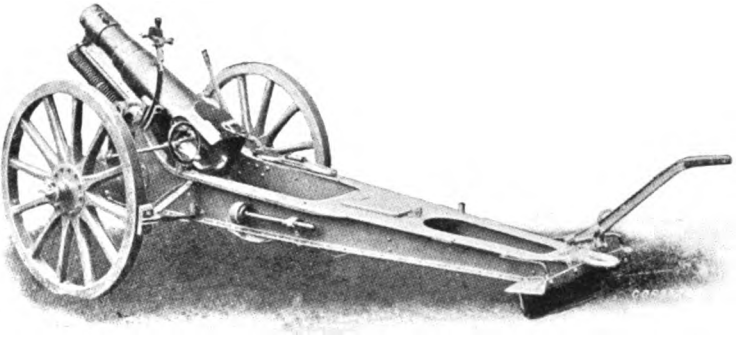

FIG. 123.

KRUPP Q. F. HOWITZER.

1902.

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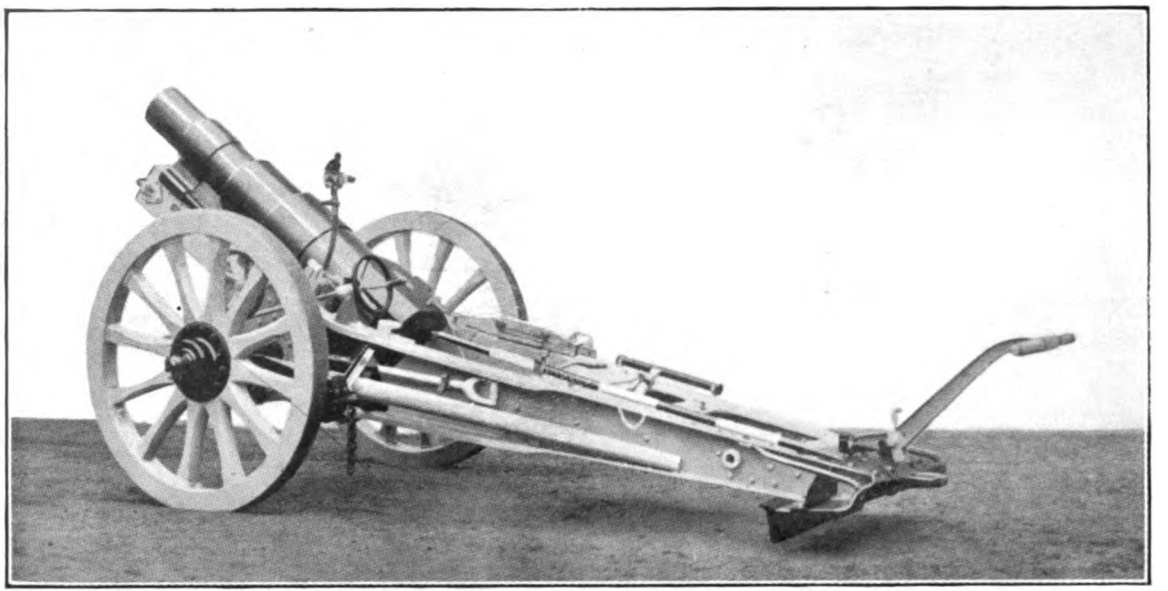

FIG. 124.

KRUPP 4.7″ Q. F. HOWITZER.

1903.

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The details are as follows—

Calibre	4.7 in.
Length	14 calibres
Weight of shell	42.2 lbs.
Muzzle velocity, full charge ...	1000 fs.
Maximum range	6400 yards
Maximum elevation	43°
Maximum depression	5°
Weight of howitzer in action ...	23¼ cwt.
Weight of howitzer limbered up ..	41 cwt.
Number of bullets in shrapnel ...	650
Weight of bullets	29 to the lb.
Weight of cartridge case	3 lbs.

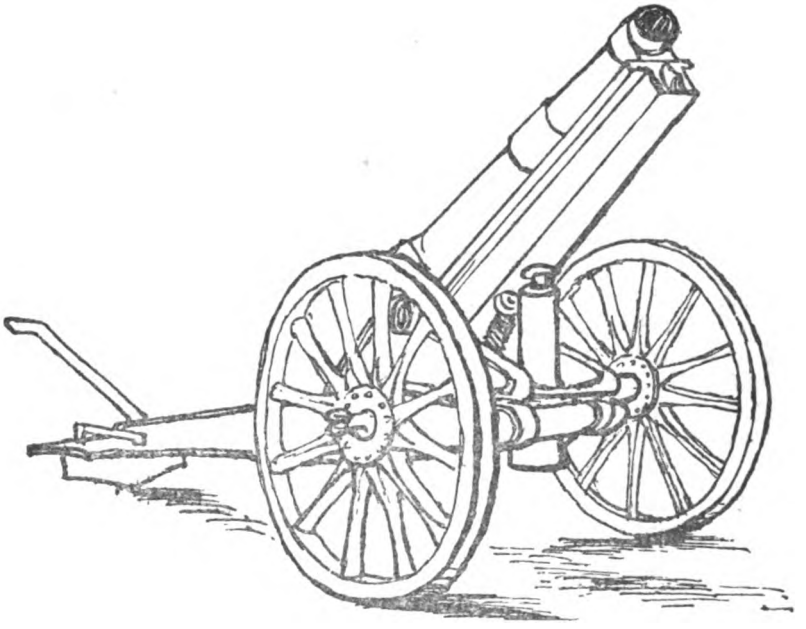

FIG. 125.
KRUPP 4.7″ Q.F. HOWITZER.
With Rear Trunnions and Constant Long Recoil.
1905.

The Krupp Long-Recoil Field Howitzer.

The equipment just described had a constant recoil of 24 inches only, and had central trunnions. But of late Messrs. Krupp have adopted the rear trunnion system with constant long recoil, and they get a recoil of nearly 4 feet at all elevations. This materially reduces the strain on the carriage and so enables a lighter construction to be used. The forward preponderance of the howitzer is balanced by a strong telescopic spring under the front of the cradle. The buffer has been simplified, and the running-up valve and Vavasseur valve described under Field Gun Equipments have been replaced by a check-buffer which has ports of varying depths.

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The howitzer and breech action are the same as those of the former equipment. The weight in action of the 4.7″ howitzer is given at 25 cwt. without shield, which is moderate for a howitzer with a muzzle energy of 310 foot-tons.

The limber has a spring limber-hook and spring draught-loops. The wagon is of the French type; 16 rounds are carried in each limber and 36 in the wagon body.

The details are as follows—

Length of howitzer	14 calibres
Weight with breech action ...	9.5 cwt.
Weight in action	25 cwt.
Weight limbered up, without shield ..	40.5 cwt.
Weight of shrapnel or H.E. shell ...	46.2 lbs.
Weight of shrapnel burster ...	7.4 oz.
Weight of H.E. burster	4.6 lbs.
Number of bullets	650
Number of bullets to the pound ...	28.5
Percentage of useful weight in shrapnel	50%
Diameter of wheels	4 feet
Muzzle velocity, full charge ...	985 fs.
Muzzle energy, ,, ,, ...	310 foot-tons
Maximum range ,, ,, ...	7600 yards
Maximum range of time fuze ...	7300 yards

Charges, 200, 30, 50, 80, and 120 grammes, total 480 grammes or 1.05 lbs.

The Krupp long-recoil 4.7″ howitzer has been adopted by Switzerland, and several batteries have been supplied to Sweden.

Messrs. Krupp also have a 4.12″ howitzer weighing 20.6 cwt. and a 5.9″ howitzer weighing 41 cwt. in action, both on the constant long-recoil system with rear trunnions.

The following ballistics of the Krupp 4.7″ howitzer have been published—

Charge	Half charge, 0.672 lbs.
Range	4265 yards
Angle of elevation	40°
Angle of descent	45°
Length of 50% rectangle	35 yards
Breadth ,, ,, ...	12.6 yards

With a full charge the rectangle is said to be much smaller.

The following figures have also been published by Messrs. Krupp:

Range.	Mean dispersion in height.	Mean dispersion in breadth.	Mean dispersion depth.
1000 yards	.9 yards	.7 yards	16 yards
2000 ,,	2.3 ,,	1.6 ,,	18 ,,
3000 ,,	5.3 ,,	3.6 ,,	23 ,,
4000 ,,	8.4 ,,	4.3 ,,	29 ,,
5000 ,,	17.3 ,,	7.0 ,,	41 ,,
6000 ,,	———	12.0 ,,	52 ,,

These figures multiplied by 1.69 give the dimensions of the 50% rectangles.

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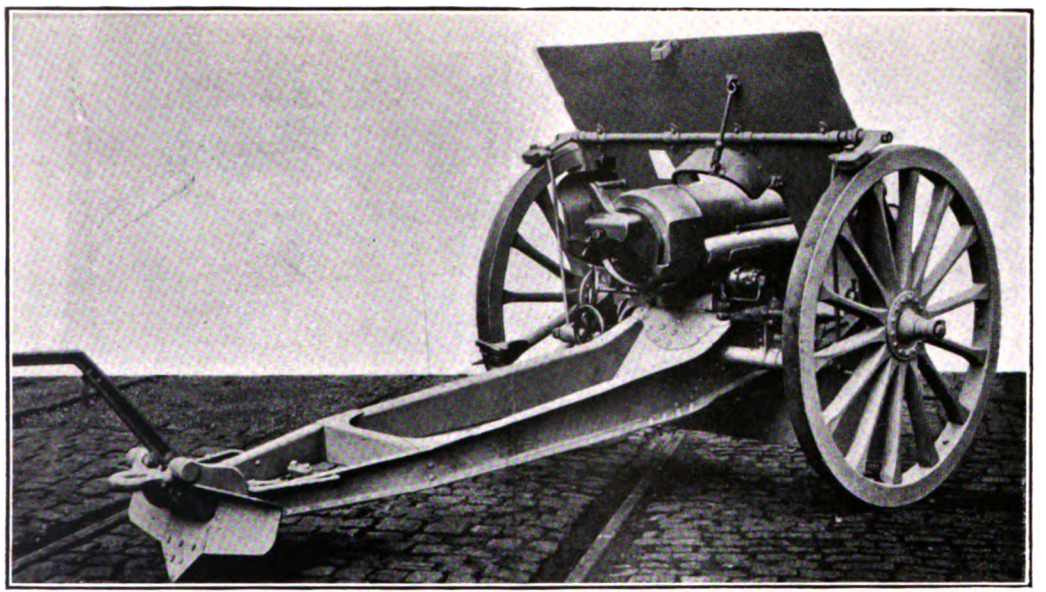

FIG. 126.

THE COCKERILL 4.7″ Q. F. HOWITZER.

1905.

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It is stated that Messrs. Krupp are experimenting with hydro-pneumatic gear for their field howitzers.

The Krupp H.P. gear is said to consist of a cylindrical air-reservoir having the buffer-cylinder and running-up cylinder within it, thus obtaining a compact construction.

One pattern has the compressed-air piston formed on the outside of the buffer-cylinder; this gives a large effective piston-area, enabling a pressure as low as 50 lbs. to the square inch to be used. Another pattern has a separate compressed-air cylinder as in the Schneider equipments.

The Cockerill 4.7" Q.F. Field Howitzer.

FIG. 126.

This howitzer has many points of originality.

The normal recoil of the howitzer on the carriage is 48", but this has to be shortened to about 24" when firing at high angles, to prevent the howitzer from striking the ground. This variable recoil is obtained by the following simple means.

On recoil, the liquid in the buffer is forced partly through the windage between piston and cylinder, partly through a by-pass channel under the cylinder. This channel can be wholly or partly closed by a stop-cock, which is connected to the right trunnion of the howitzer cradle so that as the howitzer is elevated it gradually closes the cock. At full elevation the cock is entirely closed, and the only passage remaining to the liquid is through the windage. The increased resistance thus obtained shortens the recoil to the required extent.

When the howitzer runs up after recoil the liquid passes through another channel which has a cock connected to the left trunnion. When running up at full elevation this cock is automatically thrown wide open; when running up at a low angle of elevation it is only partly opened, thus ensuring smooth running up. This arrangement is simple and serviceable, and does away with the running-up valve in the piston.

Another remarkable point is the shortness of the cradle slides as compared to the length of recoil. This is attained by interposing a sliding bed between howitzer and cradle, so that the howitzer slides on the bed and the bed on the cradle. The howitzer is thus well supported in the extreme position of recoil.

The running-up springs are of the pattern described under the Cockerill Field Gun. Twin spring-columns are used.

To increase the possible length of recoil without the howitzer striking the ground, the howitzer is made with a considerable muzzle preponderance, the trunnions of the cradle being near the breech. To lighten the labour of elevating, this preponderance is balanced by a supporting spring.

The axletree is cranked to bring the weight low.

The shield is of the folding pattern, of nickel steel, 4 mm. (.157") thick.

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The howitzer has the independent line of sight. Two sectors are fixed in prolongation of the axis of the cradle trunnions, the outer attached to the carriage, the inner to the cradle. The sight pedestal is between them, and can be clamped to either at will. To lay the howitzer the sight pedestal is set vertical by level, clamped to the inner sector, and the sight telescope directed at the target by working the elevating screw. The sight pedestal is then released from the inner sector and clamped to the outer, by one motion of a lever, and the elevation due to the range is given by the elevating screw; the sight pedestal is then again clamped to the inner sector, so that the sight now moves with the howitzer. This process appears complicated, but has the advantage of requiring only one elevating screw, instead of one elevating and one laying screw as used in the ordinary independent gear.

To allow for difference of level of wheels both sectors, with the sight between them, are made to pivot about an axis parallel to the axis of the howitzer, as in Scott's telescopic sight.

The graduations of elevation are read on the edge of the inner sector, the index or pointer being fixed to the sight pedestal. This answers the purpose of the range dial, since it always records the elevation of the howitzer above the line of sight.

A panorama sight is mounted on the pedestal, enabling an aiming point to the front, flank, or rear to be used. All graduations are in thousandths, and no degrees or minutes are used.

The limber is of the magazine pattern, and is mounted on india-rubber block springs.

The ammunition is fixed but separable, so as to allow the charge to be altered as required.

The principal details are as follows:—

Calibre	4.7″
Weight of shell	45 lbs.
Muzzle velocity, maximum	984 feet.
Total length of howitzer	56.7″
Twist of rifling, increasing from ...	4° to 12°.
Breech action	Eccentric screw.
Weight with breech action	8.45 cwt.
Height of axis	43″.
Diameter of wheels	4 ft. 4″.
Weight of wheel	150 lbs.
Weight of carriage and shield ...	13 cwt.
Total weight of howitzer in action ...	23½ cwt.
Weight of limber complete without ammunition	9 cwt.
Weight of 18 rounds	8¼ cwt.
Total weight of howitzer limbered up ...	40¾ cwt.

Messrs. Cockerill have also a 4.2″ howitzer of similar construction, weighing about 21 cwt. in action and 35 cwt. limbered up.

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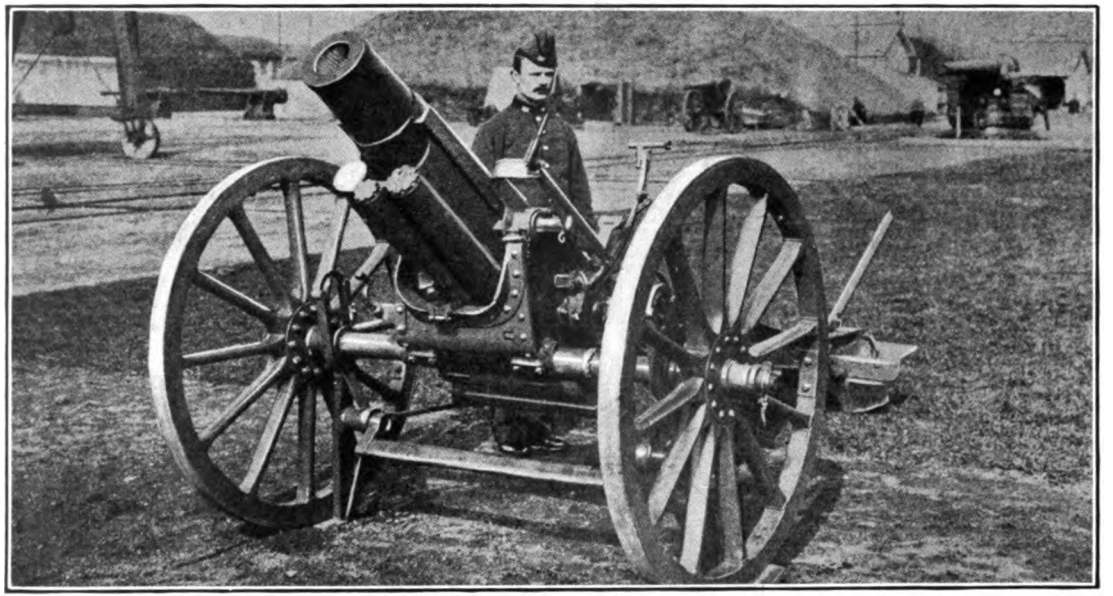

FIG. 127.

THE SCHNEIDER-CANET 6″ Q. F. HOWITZER.

1904.

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The Schneider-Canet Automobile Howitzer Battery.

FIG. 127.

Strictly speaking this howitzer is rather a weapon of position than a field howitzer. It possesses however many points of interest to the field gunner.

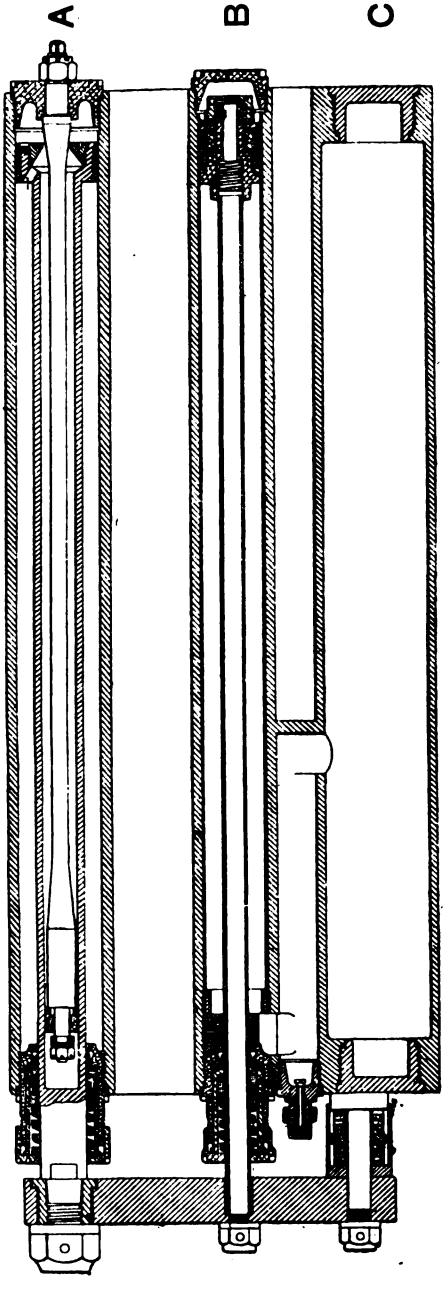

FIG. 128.

THE SCHNEIDER CANET H.P. RECOIL GEAR.

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In deciding on the armament for the great entrenched camp round Lisbon it was found necessary to provide heavy howitzers capable of being quickly shifted from point to point. Owing to the nature of the ground, the expense of a tramway would have been prohibitive, and the Committee resolved to use motors. After various experiments they decided to purchase from Schneider-Canet (Creusôt) a battery of four 6" howitzers, to be limbered up each to the breast of the carriage of the howitzer in front of it, making a train of four howitzers, the whole drawn by one motor, which also carries 64 rounds of ammunition. A second motor draws four ammunition wagons.

It has been found in practice that this motor battery can do 3¼ to 3¾ miles per hour on level roads, and half that pace up a slope of 6°. On slopes of 10° the motor goes up first and hauls the train up with a wire rope and drum. This gear is also used when necessary to haul a howitzer into position for action.

The tractor runs on petrol or oil, weighs 5 tons, and carries 7 tons of ammunition, men, and stores.

The Howitzer.

The cradle is under the howitzer and consists of a single steel forging of the shape shewn in Fig. 127.

This is bored with three longitudinal holes; "A," Fig. 128, is the buffer-cylinder, "B" the running-up cylinder, and "C" the air-reservoir.

The Recoil Gear. The buffer cylinder contains glycerine and is of ordinary construction; it has a check-buffer consisting of a plunger which extends for the whole length of the large hollow piston-rod. The packing of the gland is kept tight by a strong spiral spring, as is also that of the gland of the compressed air piston.

The howitzer has external ribs extending for its whole length; these slide upon the cradle guides when the gun recoils. There is thus no necessity for the cradle to be any longer than the buffer, namely about 4 feet. This allows of a considerable saving of weight.

The Running-up Gear. The cylinder "B" is connected with the air reservoir "C," containing air at a pressure of about 150 lbs. to the square inch. This, with an effective piston-area of 4 square inches, gives a running-up force of 600 lbs., sufficient to run the gun up smartly at any service elevation. The cylinder "B" contains glycerine, which is forced into the air-reservoir on recoil and forced out again by the air-pressure which runs the gun up. Although the air and glycerine soon get mixed up to a froth, the makers maintain that there is always sufficient liquid at the stuffing-box end of the cylinder—which is the lower end when firing at any elevation—to keep the air from escaping at the gland. The piston is kept tight by the cup-leathers as shown in Fig. 128 and is readily accessible from the front.

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In their howitzer equipments Messrs. Schneider form the buffer and running-up cylinder in the cradle, which does not recoil. The object of this is to keep the gland of the latter cylinder at the lower or rear end, so that it is always covered by the glycerine, which prevents the air from escaping. In gun equipments the breech is higher than the muzzle except when actually firing, and the opposite plan is pursued. That is, the forging containing the recoil gear and running-up gear is fixed to the gun and recoils with it. (See description of Portuguese gun.)

Messrs. Schneider have also a 4.2″ and a 4.7″ howitzer generally similar to their 6″ howitzer. The air-pressure is only 180 lbs. The 4.2″ weighs 18 cwt. in action and 34 cwt. limbered up; the 4.7″ weighs 22.5 cwt. in action and 40 cwt. limbered up.

The 6″ howitzer fires an 88 lb. shell and ranges 5 miles. It traverses on rollers along the axletree. The pedestal sight is identical with the French field gun sight, except that the collimateur is replaced by a prismatic telescope. The elevating gear is a toothed sector on the left cradle trunnion, worked by a worm wheel. A friction clutch allows the gear to slip on firing. There is the usual rapid motion for swinging the howitzer to the horizontal position for loading.

The amount of elevation given is shewn on a graduated arc; the pointer is moveable as well as the arc, the former being connected to the howitzer, the latter to the sight, so that the reading of the arc gives the true angle of elevation, independently of the angle of sight.

The breech action is the single-motion interrupted screw, of ogival pattern.

There is a folding spade on the trail, and a truck or roller can be fixed under the point of the trail. This is used when hauling the howitzer into position.

The Skoda 4.7″ Q.F. Field Howitzer.

Like the Cockerill howitzer, this has both rear trunnions and controlled recoil; the carriage is otherwise similar to that of the Skoda gun. The howitzer is unusally heavy, weighing 9.8 cwt. It has no balance spring, but an elevating arc under the muzzle end of the cradle. The weight is 24 cwt. in action without shield; the shell is said to weigh 44 lbs., M.V. 985 fs.

The St. Chamond 4.2″ Q.F. Field Howitzer.

This is similar in construction to the St. Chamond field gun already described. It is 13 calibres long and has constant medium recoil. It weighs 22.5 cwt. in action without shield, or 38 cwt. limbered up.

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The French Rimailho Q.F. Howitzer.

This is a heavy field howitzer of 6.1" calibre, firing a 95 lb. shell. It is called a field howitzer because it is divided into loads not exceeding 48 cwt. The howitzer and recoil gear travel on a special travelling carriage, the howitzer carriage travels empty save for the cradle.

The howitzer has much the same compressed-air running-up gear as the Schneider-Canet howitzer already described. It has rear trunnions, allowing a recoil of 5 feet; it traverses on the axletree, and requires to be anchored with dragshoes under the wheels in the same manner as the French field gun. The elevating gear is a toothed sector on the left cradle trunnion. The howitzer is said to have a semi-automatic and self-ejecting breech mechanism on the Schneider interrupted screw system. It has the independent line of sight and fires separate ammunition.

The shrapnel weighs 88 lbs. only, and contains 416 bullets of 18.4 to the pound, with a driving charge of 1.25 lbs The H.E. shell weighs 95 lbs. and contains 28.5 lbs. melinite. The rate of fire is given at 4.5 rounds per minute.

The French are also trying a light field howitzer to replace the present 120 mm. short gun. The latter fires a 44 lb. shell with M.V. of 910 fs., and the new field howitzer is intended to be approximately of the same power. The light howitzer is to have compressed-air gear and will traverse on the axletree; it will have the independent line of sight, and will be shielded. Calibre probably 12.5 cm. or 4.92 inches. No further details available.

Germany.

The Germans have a heavy 6" Q.F. howitzer, and are trying a light Q.F. howitzer to replace their present B.L. equipment. The latter weighs 20.5 cwt in action and fires a 28 lb. shrapnel with M.V. 1083 fs. The new howitzer will probably be of 10.5 cm. (4.13") calibre. Both Ehrhardt controlled-recoil and Krupp constant-recoil howitzers are under trial, but no decision has yet been published.

The 6" Q.F. howitzer fires an 87 lb. shell with M.V. of 905 fs. at angles up to 65° elevation. The howitzer weighs 21 cwt., and is 11 calibres long; the breech action is similar to that of the field gun (page 220). There is no shield; the weight in action is 43 cwt. There is no limber, but only a transporting axle with pintail. No gunners are carried; the weight behind the team is about 3 tons.

Russia.

The Russians are trying a 50-pounder field howitzer, M.V. 950 fs., weight in action with shield said to be about 24 cwt., wheels 4' 4" in diameter.

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America.

The Americans are trying a 3.8″ Q.F. howitzer firing a 30 lb. shell with M.V., 900 fs. The weight behind the team is the same as that of the field gun, namely 34.75 cwt. without kits or gunners, but the limber carries only a few rounds, and weighs only about 12 cwt., leaving 22.75 cwt. for the howitzer. It is also proposed to introduce a 4.7″ howitzer firing a 60 lb. shell, M.V., 900 fs. It will be interesting to see whether accurate shooting can be obtained with these relatively long howitzer shell.

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TABLE OF MOUNTAIN GUNS AND HOWITZERS.

	Armstrong.	Vickers-Maxim.	Coventry.	Krupp.	Krupp Semi-Automatic.	Ehrhardt.	Ehrhardt Controlled Recoil.	Skoda.	Bethlehem.	Schneider.	France exptl.	Howitzers. Vickers-Maxim.	Howitzers. Coventry.
Calibre, inches	2.95	2.85	2.75	2.95	2.25	2.95	2.95	2.95	3	2.95	2.65	3.3	3.3
Muzzle velocity, fs.	1070	1110	1130	920	1320	900	900	985	1100	920*	980*	910	860
Muzzle energy, foot-tons. ..	93	107	97.7	68.5	72	65.5	80	73.5	100	68.5*	76.5*	115	102
Weight of shell, lbs.	11.7	12.5	11	11.65	6	11.65	14.3	11	12	11.65*	11.5	20	20
Weight of gun, lbs.	209	280	265	231	233	242	205	230	200	215	200*	336	265
Weight of cradle, lbs. ..													
Weight of trail, lbs. ..	696	700	785	572	603	558	675	660	510	605*	650*	664	769
Weight of wheels & axle, lbs.													
Weight of gun in action, lbs. ..	905	980	1050	803	836	800	880	890	710	820*	850*	1000	1034
Length of gun, inches	48	48.5	60	42	40.5	44.5	44.5	41.5	37.25	44	?	49	54.5
Breech Action	S.B.	W	W	S.B.	W	W	W	W	S.B.	S.B.	E.S.	W	W
Diameter of wheels, inches ..	36	36	36	32	30	35.4	35.4	28.75	34	35.4*	35.4*	36	36

Doubtful figures marked *

These weights do not include shield.

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FIG. 129.

THE VICKERS-MAXIM Q. F. MOUNTAIN GUN.

1895.

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CHAPTER XXXII.

Q.F. MOUNTAIN EQUIPMENTS.

The Armstrong 1906 Mountain Gun.

This is an 11.7 pounder, M.V. 1070 fs. The gun is not jointed, and has eccentric screw breech mechanism. It is sighted on the cradle with ordinary and panorama sights.

The gun lies in a sleigh on the Krupp principle. The cradle is under the sleigh and contains the buffer and single column of running-up springs. The gun traverses on the axletree. The trail is an open trough hinged in the centre.

This gun is considerably more powerful than the Krupp and Ehrhardt equipments, and is somewhat heavier. It forms four mule-loads. The cradle, as is usual in Q.F. mountain guns, is the heaviest load, but is within the limits laid down in Chapter XI. A shield is supplied if desired; this, with two half-boxes of ammunition, forms a fifth load.

The Vickers-Maxim 1895 Equipment.

This equipment has done thoroughly good service, both in Egypt and in the Philippines.

FIG. 129.

The gun and carriage form four mule loads, namely—

		Weight with saddle and equipment,
No. 1 load ...	Gun	296 lbs.
No. 2 ...	Cradle	288 ,,
No. 3 ...	Trail	288 ,,
No. 4 ...	Axle and wheels ...	277 ,,

The gun has a single-motion interrupted screw breech-action, and fires fixed ammunition. The cradle is cylindrical, and surrounds the gun; it has two hydraulic buffers, one on either side, and two sets of running-up springs. The sights are on the cradle. The trail is of open pattern, with two plate sides and a small spade. The ammunition is packed in tubular carriers, each round in its own brass tube.

There is no shield.

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The principal detail are as follows—

Calibre	2.95 in.
Muzzle velocity	925 fs.
Muzzle energy	73 foot-tons.
Weight of shell	12½ lbs.
Weight of gun	236 lbs.
Weight of cradle	194 lbs.
Weight of trail	224 lbs.
Weight of wheels and axle ...	192 lbs.
Weight of gun in action	846 lbs.
Length of gun	36 in.
Diameter of wheels	34 in.

The Vickers-Maxim 1905 Q.F. Mountain Gun.

As will be seen from the Table, this is a considerably more powerful gun than the old V.M. equipment. It is shielded and has a folding trail 7.5 feet long. The construction is generally similar to that of the V.M. field gun already described, except that the breech action is the single-motion wedge. The gun has both goniometric and panorama sights; it has not the independent line of sight.

The gun is not jointed, but the breech ring and mechanism are carried separately, thus reducing the load of the gun mule.

The total loads, including saddle and equipment, spare parts, etc., are as follows:—

1.	Gun and shield	239 lbs.
2.	Front and rear end of the trail ...	294 lbs.
3.	Breech ring and mechanism, Middle portion of trail ...	280 lbs.
4.	Cradle, elevating and traversing gear	300 lbs.
5.	Wheels and axletree	286 lbs.

The Coventry Ordnance Works.

This is a 5-mule equipment intermediate in power between the Armstrong and Vickers-Maxim. The gun is in one piece, and is of unusual length for a mountain gun, namely 60 inches. This enables the calibre to be reduced to 2.75 inches, which is better suited to an 11 lb. shell than 2.95". The breech action is the Ehrhardt wedge illustrated on page 220. The gun has not the independent line of sight; it has an all-round panorama sight which can be cross-levelled for difference of level of wheels.

The following details have been published in addition to those in the Table:—

Weight of shrapnel and H.E. shell ...	11 lbs.
No. of shrapnel bullets	200.
,, ,, ,, to the pound ...	41.
Weight of recoiling parts	350 lbs.
Maximum elevation	25°.
Traverse each way	2½°.
Length of recoil	33 inches.
Length of trail	8 feet.
Thickness of shield	0.125 inches.

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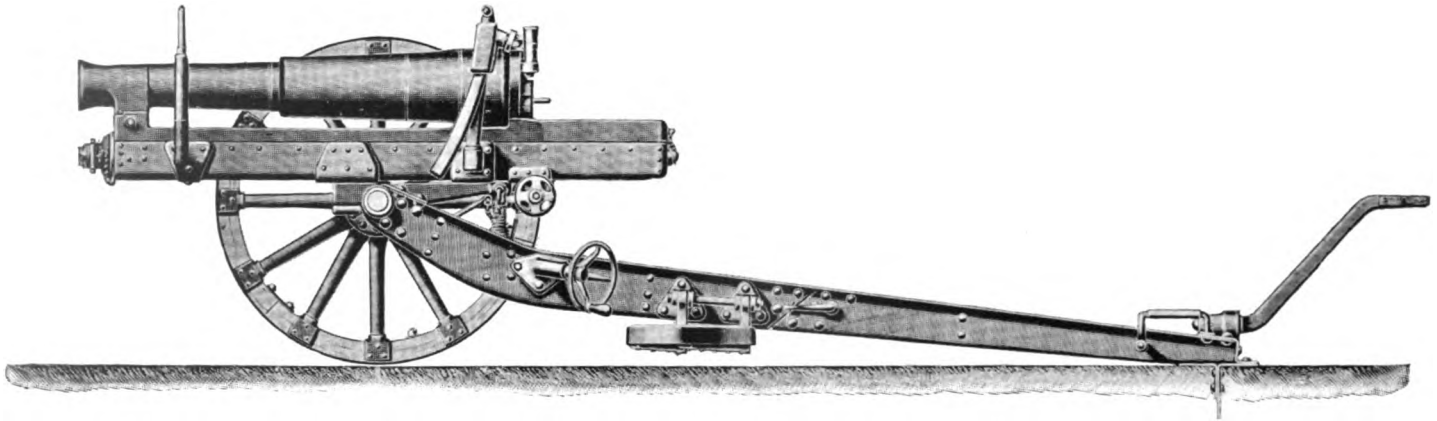

Fig 130.

THE KRUPP 75 mm. MOUNTAIN GUN.

1904.

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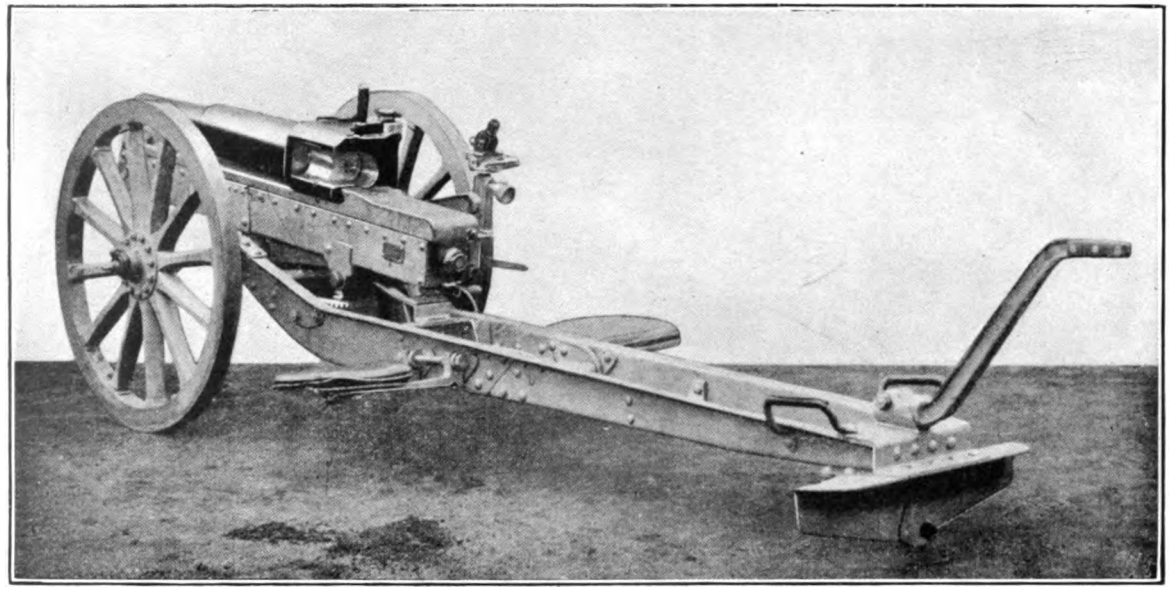

Fig. 131.

THE KRUPP SEMI-AUTOMATIC MOUNTAIN GUN.

1905.

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The Krupp Q.F. Mountain Gun.

FIG. 130.

This gun is distinguished by the Krupp *sleigh*, already referred to, which is interposed between the gun and the cradle, and which facilitates the assembling of the gun for action. Except for this and for the divided trail, the equipment is similar to the Krupp Q.F. field gun.

The following details have been published in addition to those given in the Table :—

Length of bore	34.75″.
Weight of wedge	42.8 lbs.
Number of grooves	28.
Depth ,, ...	0.019″.
Width ,, ...	0.232″.
Twist ,, ...	1/45 to 1/25.
Length of rifling	30″.
Number of bullets in shrapnel ...	225.
Number of bullets to the pound ...	41.
Diameter of chamber at rear ..	3.14″.
,, ,, front ...	3.015″.
Sighting radius	28.3″.
Max. elevation	20°.
Max. range	4600 yards.

No shield is included in the equipment, but a shield 0.14 thick weighing 80 to 100 lbs. is supplied if desired.

The net loads are as follows, not including saddle and equipment :—

Gun mule	264 lbs.
Cradle mule	220 lbs.
First trail mule, with axle	185 lbs.
Second trail mule, with wheels and shafts	209 lbs.

The cradle forms an awkward load, being 4′ 6″ long. With 60 lbs. of saddle and equipment it weighs 350 lbs., which is beyond the limit considered advisable in our service.

The Krupp Semi-Automatic Mountain Gun (1905).

Fig. 131.

This is a small-bore gun throwing a shell of only 6 lbs. with a high velocity. The semi-automatic action is as follows: A rod connected to the breech action leads forward on the right-hand side of the gun, and has a projection on its fore-end. There is a tripper on the cradle which allows this projection to pass during recoil. On running-up the tripper catches the rod, which throws open the breech and ejects the cartridge-case. The breech then remains open, and is held open by the extractor. When the fresh cartridge is inserted, as soon as it pushes home the extractor the wedge breech-block is released and closes by a spring.

This action enables one of the gunners serving the gun to be dispensed with. This is important in view of the small amount of cover afforded by the shield of a mountain gun.

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This gun travels either on mule-back or in shaft-draught. It is intended either as a mountain gun or as a "battalion gun" to advance with the infantry firing line.

The Krupp Mountain Sight.

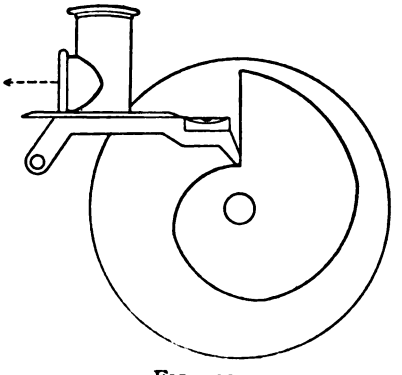

FIG. 132.
DIAGRAM OF KRUPP MOUNTAIN SIGHT.
(View from left side.)

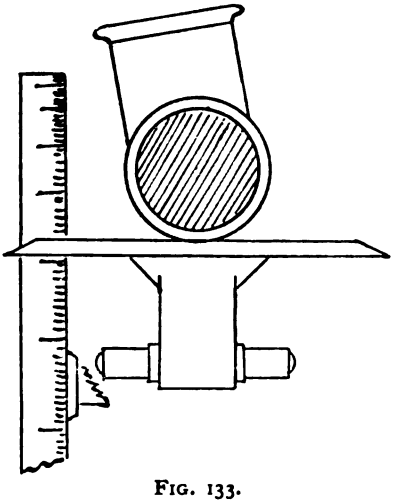

FIG. 133.
DIAGRAM OF KRUPP MOUNTAIN SIGHT.
(Front view.)

This was exhibited at Milan in 1906. It consists of a short telescope bent at right angles, mounted on a rocking bar. One end of the bar is supported on a spiral cam; on the same axis as the cam is a drum about 24″ in circumference, graduated in metres of range. The bar also carries a clinometer level adjustable for angle of sight. The whole sight can be mounted on a pivot parallel to the axis of the gun, so that it can be cross-levelled to correct for difference of level of wheels. The telescope is mounted on a graduated circular plate, so that it can be directed on an aiming point at any angle.

The telescope has a large field, apparently of about ten degrees, and is of low magnifying power. On looking down into it from a distance of a few inches the layer sees a brightly-illuminated picture of the foreground, with a pointer in the middle of the field.

The gun shown at Milan was sighted on the right-hand side at the extreme rear end of the cradle, well clear of the wheels. The telescope was inclined to the right, presumably for the convenience of the layer, so that he should not have to put his head behind the recoiling gun.

The whole sight is remarkably simple and compact; it has no verniers or other complications, and there is nothing about it likely to go wrong. It would be an easy matter to put a fuze scale and corrector scale on the face of the drum.

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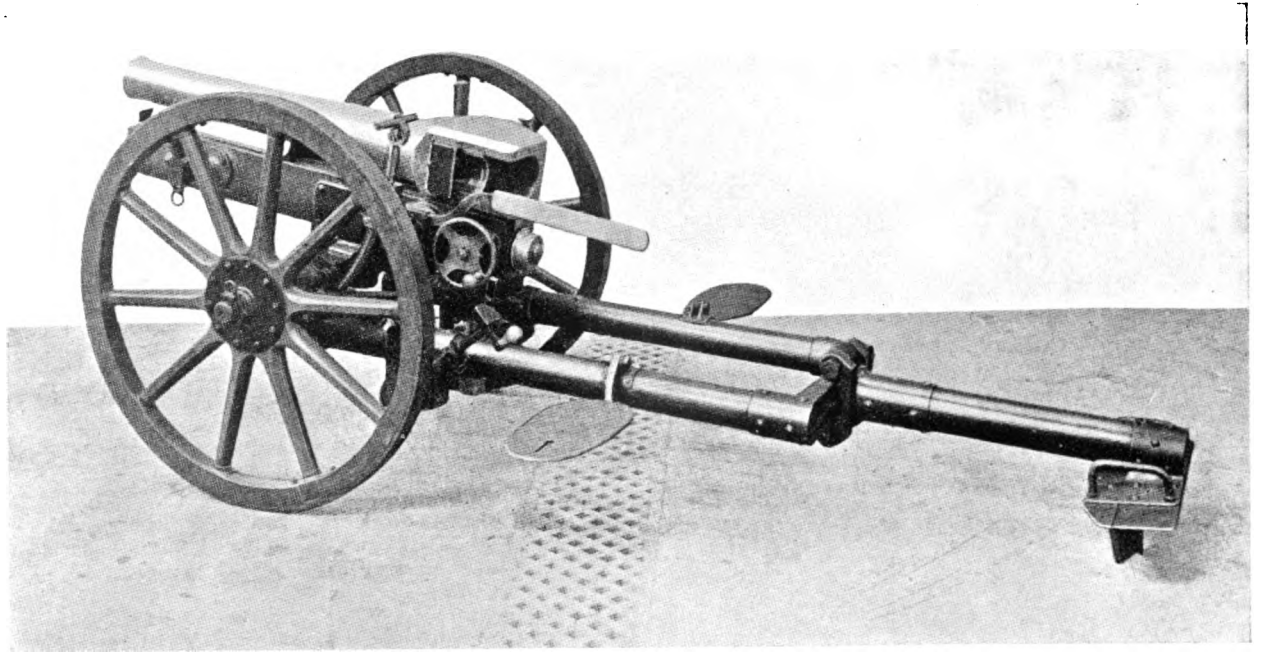

FIG. 134.

EHRHARDT 75 mm. Q. F. MOUNTAIN GUN.

1903.

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The Ehrhardt Mountain Gun (1903).

Fig. 134.

This is a 2.95″ gun firing a shell of 11 lbs. 10 oz. with M.V. 900 fs. It is a reduced copy of the Ehrhardt field gun, having a cradle pivoted in a socket in the axletree. The trail is of Y shape and folds for travelling. The gun has the Ehrhardt wedge breech and is sighted on the cradle with arc and panorama sights. The elevating gear gives no less than 25° of elevation. The shield is unusually large and is recessed to fit over the wheels and to project beyond them. It weighs 99 lbs. It may be noted that a shield so small as to fit between the wheels of a mountain gun affords little real protection. If a mountain gun is to have a shield at all it is as well that it should be a serviceable one. A pair of shafts is carried for travelling on roads.

The equipment is divided into four equal loads of 242 lbs. net, namely gun, cradle and shield, trail and wheels, axle and shafts. The cradle is unusually light, weighing only 143 lbs.

The Ehrhardt Controlled Recoil Mountain Gun (1905).

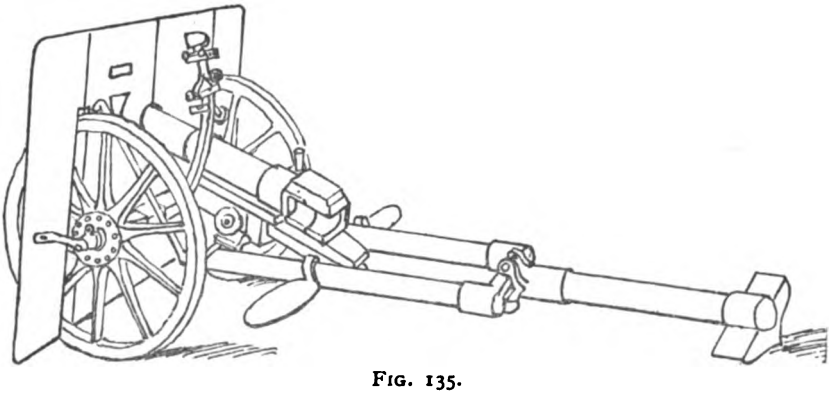

Fig. 135.

EHRHARDT 75 mm. CONTROLLED RECOIL MOUNTAIN GUN.
In Recoil Position.

This is a powerful gun, throwing a shell of 14.3 lbs. weight, M.V. 900 fs.

It is but little heavier than the Ehrhardt 12 pr. mountain gun; the extra power, combined with steadiness, is obtained by the controlled recoil gear already described, which enables the gun to be kept low on the carriage without any risk of the breech striking the ground when firing at elevations up to 38 degrees. The equipment is otherwise similar to the 12 pr., but the shield is only 3 mm. thick instead of 3½ mm., and weighs 77 lbs. Another point of difference is that in the 14.3 pr. the guide-blocks are not permanently fixed to the gun, but remain on the cradle when the gun is lifted out of them, on the same principle as that of the Krupp sleigh.

The gun is carried in four equal loads of 210 lbs. net; a fifth mule carries the shields for two guns. The four loads are: gun, cradle with guide-blocks, trail and wheels, axle and shafts.

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Two batteries of Ehrhardt mountain guns were supplied to Portugal for the Angola expedition which was to have started in 1906; and two batteries have been supplied to Holland for use in Further India.

The Skoda 1904 Mountain Gun.

Fig. 136.

This is an 11 pr., M.V. 985 fs. The gun is in one piece, and has the Skoda wedge breech mechanism, with knuckle-jointed locking gear. The gun lies in a sleigh on the Krupp system. It is sighted on the cradle with arc and panorama sights.

The cradle is under the gun, and contains the buffer and single column of springs. It is of U section, with the edges turned in; the guides on which the sleigh slides are *inside* the cradle. The cradle is pivoted on a vertical trunnion on a saddle between the trail brackets. The buffer does not recoil with the gun; it is of the ordinary type with check-buffer. Being completely filled with glycerine, it has to be fitted with a valve to allow air to escape, in case air is sucked in during the run-up. The gun has worm-wheel traversing gear and the ordinary double elevating screw.

The trail is of the open pattern, with bracket sides, and is jointed in the middle. The front half is carried with the axletree in position; the rear half is carried with the wheels.

The gun without the shield forms four loads, namely gun 230 lbs., cradle 237, fore end of trail with axletree 205, point of trail and wheels 221 lbs. net. These loads are slightly heavier than ours, but presumably Austrian mules are well up to weight. It is proposed to carry the shield (60 lbs.) with the fore end of the trail, making a total net load of 256 lbs.

The Bethlehem Q.F. Mountain Gun.

This equipment is of novel construction. The gun, when brought into action, is dropped into a sleigh on the same principle as in the Krupp mountain equipment. But the Bethlehem sleigh contains, or

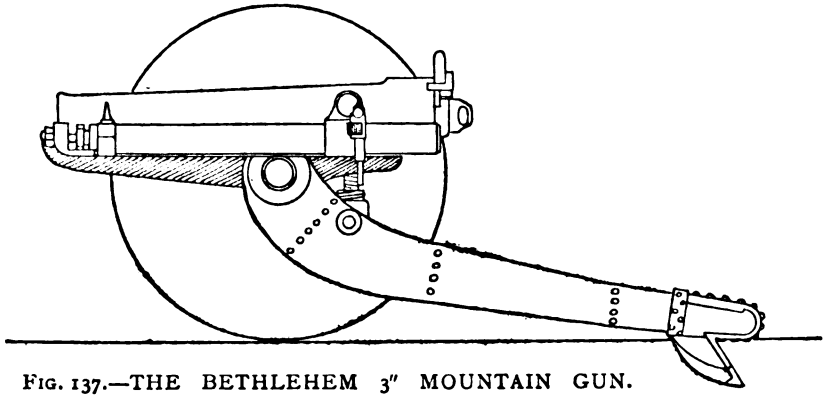

FIG. 137.—THE BETHLEHEM 3″ MOUNTAIN GUN.

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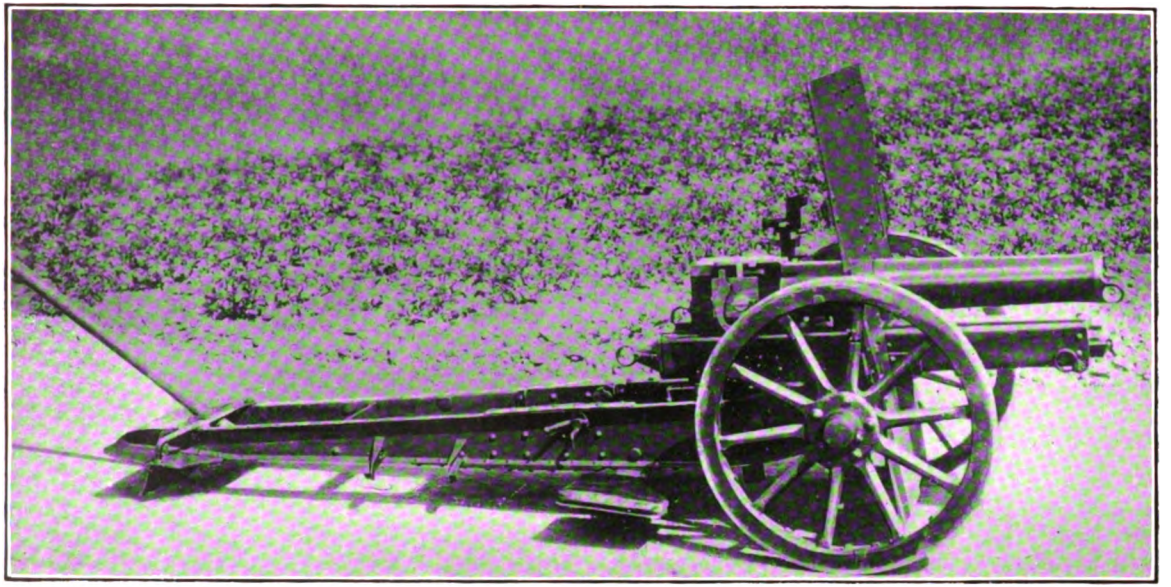

Fig. 136.

THE SKODA 75 mm. Q. F. MOUNTAIN GUN.

1905.

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rather consists of, the twin buffers and the springs, which are inside them. The whole of these parts recoil with the gun except the piston rods.

There is no cradle, but a guide-bar upon which the gun and the sleigh recoil; the front of this is forked and turned up to receive the end of the piston rods.

This construction is ingenious, and well suited for a mountain gun. The weight of the gun is kept at a minimum, and all working parts are well protected. The gun is a powerful one; it is of 3 inches calibre, throwing a 12 lb. shell with M.V. of 1,100 fs. and M.E. of 100 foot-tons. The gun, carriage, and 8 rounds make 4 loads of 206 lbs. net, without saddle.

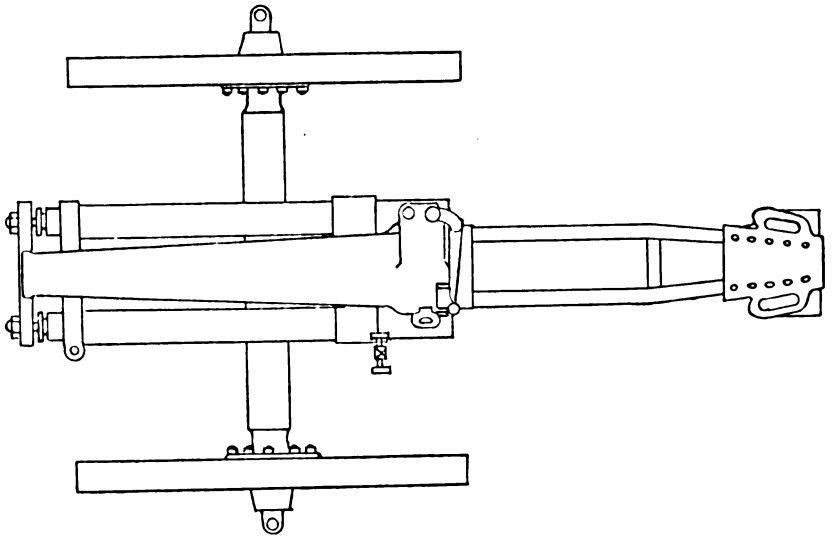

FIG. 138.—THE BETHLEHEM 3" MOUNTAIN GUN.

THE Q.F. MOUNTAIN HOWITZER.

A mountain howitzer is a gun throwing a heavy shell at a high elevation, and capable of being transported on pack animals.

The difficulty in the way of its construction lies in the small space available between the howitzer and the ground, which renders it difficult to allow of long recoil without the breech striking the ground on discharge. (See page 89). On the other hand, the mountain howitzer is not expected to travel across country on its wheels, so that it can be set proportionately higher than a field gun. The difficulty is usually met by a combination of rear trunnions and controlled recoil, but even so it is not easy to secure sufficient space for recoil within permissible limits of weight.

Q.F. Mountain Howitzer Equipments.

These are still more or less in the experimental stage, and makers are reticent as to the details of construction.

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Vickers Sons and Maxim have a mountain howitzer of which some details are given in the Table. The howitzer is not jointed, but the breech ring and mechanism are carried separately, thus reducing the weight on the gun mule. The equipment is divided into six loads. Including saddle and equipment the total loads are as follows:—

1.	Howitzer	270 lbs.
2.	Buffer and springs, etc.	269 ,,
3.	Cradle, breech-ring, and breech action	269 ,,
4.	Front end of trail and shafts ...	259 ,,
5.	Rear end of trail, tools, etc. ...	267 ,,
6.	Wheels, axle, and stores	258 ,,

These loads are well within the limits laid down in Chapter XI.

This equipment introduces a new principle in construction, namely dividing the gun not across the bore, but behind the cartridge. The whole breech-piece, containing the breech-block or wedge, is removable, and is carried separately. In the the V.M. equipment this reduces No. 1 load by 116 lbs.

The Coventry Ordnance Works.

This firm has a mountain howitzer equipment of which the details are given in the Table. It differs from the V.M. equipment in that the M.V. is 50 fs. less; this enables the weight of the howitzer and breech action to be kept down to the 265 lbs. limit. The howitzer is 14.7 calibres long as against 13 for the V.M.; this enables the required muzzle energy to be obtained with less metal in the howitzer. The total weight of gun and carriage is about the same in the two equipments.

MOUNTAIN EQUIPMENTS OF VARIOUS NATIONS.

Most Continental nations have already semi-Q.F. mountain equipments of the spring spade type. These are now being replaced by gun-recoil equipments.

France is trying a mountain gun similar in construction to her field gun, with compressed air running-up gear (this is doubtful), Nordenfeldt eccentric screw breech, and traverse on the axletree. The calibre is 6.5 cm. or 2.56″; weight of shell 11.5 lbs., M.V. about 980 fs., weight in action about 850 lbs., gun in one piece. It is also reported that France is trying a mountain howitzer on the Schneider system, in two parts, with compressed air running-up gear, weight of shell 22 lbs.

Germany is said to be trying the Krupp and Ehrhardt equipments, and may adopt a mountain gun and howitzer containing the best feature of both.

Switzerland and Turkey have bought 75 mm. Krupp mountain guns, and *Italy* is trying one.

Portugal has bought mountain guns of Ehrhardt. *Bulgaria* has adopted the Schneider mountain gun, calibre 2.95″, length 13 calibres, weight 215 lbs., in one piece.

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The *Austrians* are trying to make their field howitzers available for mountain work by putting them on narrow-gauge carriages of 1 metre track. This system is of great value in Central Europe, where most mountains, up to the snow line, are traversed by fairly easy tracks. But it does not constitute a true mountain equipment.

Russia.

The Russian 1904 Q.F. mountain gun is of 2.95″ calibre, firing shrapnel and H.E. shell, weighing 14.3 lbs., M.V. 920 fs. Fixed ammunition is used. The gun weighs 221 lbs.; the trail is in two pieces. The equipment forms 5 loads. Except the Vickers-Maxim 1905 gun, this is the most powerful mountain gun in existence.

Japan.

The Japanese gun is a smaller edition of the field gun described in the last chapter. It is not a true quick-firer. It fires shrapnel and H.E. shell of 13.2 lbs., M.V. 900 fs. Fixed ammunition is used. The gun is of 2.95″ calibre, 40″ long, rifled with uniform twist of 1 in 25 calibres, swinging block breech action, weight 220 lbs. The trail is in two parts. The carriage gives 30° elevation and 10° depression. The height of the wheels is 40″, track 28″. The equipment forms four mule loads.

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Part V.

GUNNERY CALCULATIONS.

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CHAPTER XXXIII.

ON THE USE OF THE PLOTTING CHART.

Much labour may be saved in Artillery calculations by the use of simple graphical methods. Suppose, for instance, that it is required to construct a range table for the 15-pr. Q.F. gun firing 15-pr B.L. shell. Instead of calculating elevations, remaining velocity, etc., for each 100 yards, we work out the figures for 1000 yards, 2000 yards, and so on, plot the results on a chart, and with the assistance of a flexible cane or "spline" we draw a curve passing through all the points plotted. From this curve we obtain by simple direct measurement the figures for every hundred yards of range.

Thus, in the above instance, take a sheet of paper say 18″ wide by 24″ high. Near the bottom of it rule a line 14″ long, marked off into 2-inch divisions; then each 2-inch mark stands for 1000 yards, and the whole line for 7000 yards. At the right-hand end erect a perpendicular 15″ high, divided into 30 parts, and let each part stand for one second; at the left-hand end erect a perpendicular 20″ high, and let each inch stand for one degree of elevation.

To make out the table of elevation, calculate by Table X. of the Text Book the elevation for 1000 yards, which we find is 1° 18′, or 1.3°; make a dot on the chart 1.3″ above the 1000-yard mark on the bottom line. For 2000 yards the elevation is 3 degrees; make a dot 3″ above the 2000-yards mark on the bottom line, and so on. Drive a pin into each dot, and press a flexible cane against the pins till it touches all of them; then draw a curve passing through all the dots. To find the elevation for any range we have only to measure from the curve down to the bottom line. Thus at 5200 yards the curve is 14″ above the bottom line, therefore the elevation for 5200 yards is 14 degrees.

The curves for the time of flight, remaining velocity, and angle of descent may be drawn in similar fashion.

Even when a number of results have to be determined by calculations, it is useful to plot them. Any accidental error in a figure will then be shown up by an irregularity in the curve.

The plotting chart is useful at annual practice for working out a reliable fuze scale. This is especially the case when a new mark of fuze is issued for practice, as the official scale is frequently found to require modification.

The method is as follows—Whenever the practice report shows that the range was found within 25 yards, and the effect shows that the fuze was a good one, the fuze is accepted as correct for the range and plotted on the chart, having first been corrected for a standard

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height of barometer. If this is done for every good fuze found by each of the batteries, then after a few days of battery practice it will be possible to draw a curve which will give the correct fuze for any intermediate range.

Similarly, if desired, the error of each of the 18 layers in each series layed by him may be plotted on curves, affording a valuable means of comparison.

The graphic method may be applied to the easy solution of questions which would otherwise require to be solved by Higher Mathematics. Thus, in the article in this book on the gun-wheel, it was required to find the depth of a segment of a 3-foot wheel which should have an area of 10 inches.

Now the formula for the area of a segment is

$$\text{Area} = \pi r^2 \frac{A}{360} - \frac{r^2}{2} \sin A$$

where A is the angle subtended by the segment at the centre of the circle. This equation is not easy to solve algebraically. But with the assistance of the plotting chart it is a simple matter.

Draw a horizontal scale of equal parts for square inches of area, and a vertical scale of equal parts for degrees of angle. Guess the required angle at 47°, and work out the area of the segment; it proves to be 14.3 sq. in. Plot this on the chart, making a dot 47 inches (or rather 7 inches, since the 40 can be omitted) over point 14.3 on the horizontal scale. Try 43°, and we get 11 sq. inches; 40° gives us 8.75 inches. Now draw a curve through the 3 points plotted (it is nearly a straight line) and measure up from the point denoting 10 square inches to the curve. The distance is $1\frac{3}{4}$ inches; therefore the required angle is $41\frac{3}{4}°$ or 41° 45′. From this the depth of the segment is found by elementary trigonometry, the equation being

$$d = r \left(1 - \text{Cos} \frac{41° 45'}{2} \right)$$

where r, the radius of the wheel, is 18 inches

To a gunner with a slide-rule, a plotting-chart, and a knowledge of elementary mathematics, few artillery problems should present any difficulty.

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CHAPTER XXXIV.

Trigonometrical Tables.

In the Text Book of Gunnery, page 346, will be found a table dealing with sines, tangents, and so forth. For the benefit of officers who have forgotten their trigonometry the following elementary explanation is given. Mathematicians are warned off.

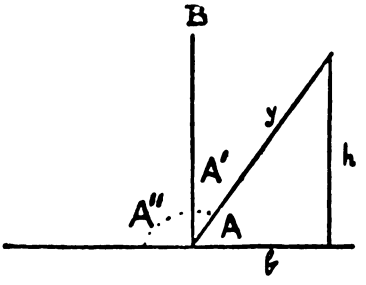

Fig. 139.

Let A be an angle contained by two lines. Let a perpendicular be dropped from any point in one line upon the other. We have then a right-angled triangle with height h, base b, and hypotenuse y. Then the fraction formed by dividing the height by the hypotenuse, h/y, is called the *sine* of the angle; the base over the hypotenuse, b/y, is the *cosine*; the height over the base, h/b, is the *tangent*, and the base over the height, b/h, is the *cotangent*. The hypotenuse over base, y/b, is the *secant*, and the hypotenuse over height, y/h, is the *cosecant*.

If a line AB be drawn at right angles to the base, then the angle A′ required to complete the right angle is called the *complement* of A. It will be obvious on inspection that the sine of an angle is equal to the cosine of its complement, tangent to cotangent, and secant to cosecant. This enables a table of sines, &c., to be simplified, the same figure standing for the sine of 30° and the cosine of 60°. Sines, tangents, and secants are read from the top of the table; cosines, cosecants, and cotangents from the bottom.

If in the figure the base be continued to the left so that the angle AA″ forms a complete half-circle, then the angle A″ is called the *supplement* of A; and its sine, cosine, &c., are the same as those of A. This is useful to remember when dealing with angles greater than a right angle. Thus if we have to find tan 105° we should look out tan 75° in the table.

The above trigonometrical tables are frequently used in artillery problems.

For instance: The calculated angle of opening of a shrapnel is 14°; what will be the lateral spread of the bullets at 100 yards from the burst?

Here AB = 100 yards: by table BC/AB = tan 7° = 0.12278: therefore BC = 0.12278 × 100 yards = 12.278 yards: therefore CC = 24.556 yards.

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For angles up to 2 or 3 degrees it will be found sufficient to use the gunner's rule, that "a minute is equal to an inch at 100 yards. Thus 35 min. subtends 35 in. at 100 yards, 40 in. at 120 yards, and 400 in. at 1200 yards. This is expressed in the rule for correcting deflection by the formula "Reduce the error to inches and divide by the number of hundreds of yards in the range," thus an error of 6 ft. right at 2400 yards requires $\frac{6 \times 12}{24} = 3$ minutes left deflection.

MENSURATION.

Solution of Triangles.

This is a problem which frequently occurs in practical gunnery calculations.

When two angles are known the third is also known, since the three angles of a triangle are together equal to 180 degrees. And if one side is known, either adjoining side can be found, since sides are proportional to the sines of the angles opposite to them. Thus in a triangle ABC:

If the angle A be 20°, and B 85°, then C = 180 − 105 = 75°; if the side AC be 100 feet long, then $\frac{AB}{AC} = \frac{\sin C}{\sin B} = \frac{9659}{9662} = .9694$; then AB = .9694 × 100 feet = 96.94 feet.

If two sides and the included angle be known, the simplest way is to divide the triangle into two right-angled triangles.

In a triangle ABC drop a perpendicular BD upon the base AC. Suppose we know A, AB, and AC; then in the left-hand triangle we know all three angles and the side AB, which enables us to find BD and AD; hence we know DC. Then the square on BC is equal to the sum of the squares on BD and DC, which gives us BC, and the triangle is solved.

To find the angles of a triangle, having given the three sides, the shortest way is to draw it.

The area of a triangle is equal to the base multiplied by half the height; thus the triangles A and B are of equal area.

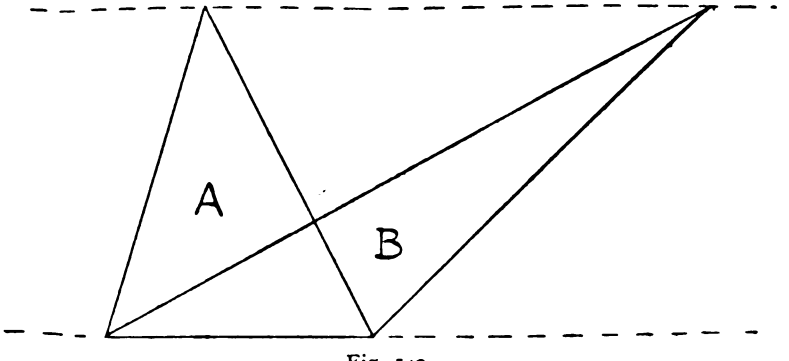

Fig. 140.

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Rectilinear Figures.

The area of any plane rectilinear figure may be obtained graphically by dividing it into triangles and rectangles, as A B C, or by reducing it to one triangle, working on the principle that any two triangles on the same base and between the same parallels are equal.

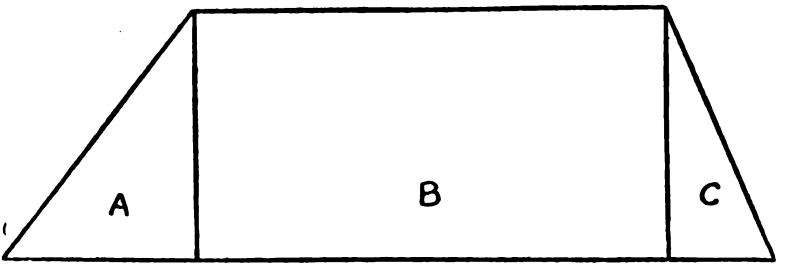

FIG. 141.

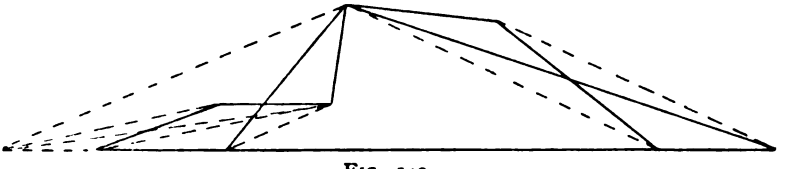

FIG. 142.

Circle.

Let r be the radius; then

Circumference $= 2\pi r$

Area $= \pi r^2$

where $\pi = 3.14159$ or $\frac{22}{7}$.

Log. $\pi = .4971496$: log. $\frac{1}{\pi} = 1.5021508$.

Sector of Circle.

Let A be the number of degrees which the arc subtends at the centre:

Then length of arc $= \frac{\pi r A}{180}$

Area of sector $= \frac{1}{2}$ arc $\times$ radius

$$= \frac{\pi r^2 \times A}{360}$$

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Segment of Circle.

$$\text{Area} = \text{area of sector} - \text{area of triangle}$$
$$= \frac{\pi r^2 A}{360} - \frac{r^2 \sin A}{2}$$

Where H is the height, and B the base, then for a flat segment:

$$\text{Length of arc} = B + \frac{8H^2}{3B}$$

This is useful when using the Distance Table, as it gives an approximation to the actual distance travelled by the shell.

Cylinder.

$$\text{Volume} = \text{area of base} \times \text{perpendicular height}$$
$$= h \times \pi r^2$$

Cone.

$$\text{Volume} = 1/3 \text{ circumscribing cylinder}$$
$$= 1/3\ h \times \pi r^2$$

Pyramid.

$$\text{Volume} = 1/3 \text{ circumscribing prism}$$
$$= 1/3 \text{ area of base} \times \text{height.}$$

Sphere.

$$\text{Volume} = 2/3 \text{ circumscribing cylinder}$$
$$= 2/3 \times 2r \times \pi r^2$$
$$= 4/3\,\pi r^3$$
$$\text{Surface} = 4\,\pi r^2$$

USE OF FOUR-FIGURE LOGARITHMS.

To find the log of a number.

Open the Four-Figure Log Table, and look up the first two figures of the number in the first column, and the third figure in the columns 1 to 9 which follow; to the log there found add the difference for the fourth figure taken from the columns 1 to 9 on the right of the table. This is the decimal part of the log; for the integral part set down the number of integral figures in the number, less one.

Thus the integral part of the log of a number is—

Number 1	...	...	0
Number between 1 and 10	...	...	0
,, ,, 10 and 100	...	...	1
,, ,, 100 and 1000	...	...	2
,, ,, 1000 and 10,000	...	...	3

and so on.

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Number between 1 and .01	...	$\bar{1}$
,, ,, .01 and .001	...	$\bar{2}$
,, ,, .001 and .0001	...	$\bar{3}$

and so on.

Remember that the decimal part of a log is always positive, though the integral part may be negative; for this reason the minus sign is put over the integral part instead of in front of the whole log.

Example—Log 1728 = 3.2375; log 6 = .7782;
log 15 = 1.1761; log 0.3 = $\bar{1}$.4771; log 0.456 = $\bar{1}$.6590;
log 0.0047 = $\bar{3}$.6721.

To multiply two numbers, add their logs. Thus log (1783 × 36.41)

$$\begin{array}{r} 3.2511 \\ 1.5612 \\ \hline = 4.8123 \end{array}$$

Now in the table of numbers to logs look up .812, and add difference for 3, making 6491; since the integral part of the log is 4, the number is in tens of thousands; therefore the result is 64910. The correct product by multiplication is 64919.03, which gives some idea of the amount of accuracy to be expected when using four-figure logs. For accurate work Chambers' table of seven-figure logs should be used.

Similarly, 349 × .0043 = 1.501

$\bar{2}$.5428
$\bar{3}$.6335
0.1763

To divide one number by another, subtract the log of the divisor from that of the dividend—

$$\frac{348}{5312} = .05428$$

2.5416
3.8070
$\bar{2}$.7346

Beginners often find some difficulty in subtracting the log of a decimal less than unity; this can be overcome by remembering the algebraical rule, "change the sign of the divisor and add."

Thus $\frac{146}{.0023} = 63490$

2.1644
$\bar{3}$.3617
4.8027

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To square or cube a number, multiply the log by 2 or 3; to find the square or cube root, divide by 2 or 3.

Thus $321^2 = 102800$

$\sqrt[3]{480} = 7.829$

$\sqrt[2]{.0035} = .05916$

	2.5065
	2.5065
	5.0120
3	2.6812
	.8937
2	$\bar{3}.5441$
	$\bar{2}.7720$

This last is a tricky piece of arithmetic, and the division is most easily accomplished by writing the log in two parts, $\bar{4} + 1.5441$, and adding the results together after division, making $\bar{2}.7720$.

THE SLIDE RULE.

This instrument enables calculations to be performed with about the same degree of accuracy as the table of four-figure logs. It is quicker to use, and certainly less fatiguing and less liable to error. Some notes on it will be found in the Text Book of Gunnery.

The best slide-rule I have met with is Colonel Anderson's 12-inch rule. This has 4 parallel scales on each limb, making it equivalent to a rule 48 inches long. It is sold by Casella & Co., Rochester Row, Westminster.

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APPENDIX.

THE EVOLUTION OF A FIELD GUN.

Reprinted from the Journal of the Royal Artillery.

This Essay is intended as an illustration of the practical application of the Principles of Construction enunciated in this book.

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NOTE BY THE AUTHOR.

The gun described in the following pages was designed in 1904. To bring it up to date several modifications would be necessary. Thus the writer would be disposed to do away with the running-up springs and substitute the Schneider compressed-air gear as used in the Portuguese gun. This, by increasing the recoiling weight, would enable the recoil to be shortened. The weight thus saved in the cradle would be used to increase the thickness of the shield. For in view of the increased penetration of the German S bullet and the French D bullet, a thickness of 3½ millimetres is no longer considered sufficient.

The buffer itself might be improved by abolishing the check-buffer and substituting a Vavasseur valve in the piston.

The shortened cradle would necessitate pivoting the gun farther forward than the axletree in order to get a moderate trail lift. This could best be done by setting the vertical cradle trunnion in a saddle supported on horizontal trunnions between the trail brackets, as in the German gun. This construction allows of an automatic correction for drift being given by inclining the saddle trunnions at an angle to the horizontal. It also allows the axletree to be cranked 3″ downwards, which reduces the length of the trail by nine inches for the same trail angle.

This reduction in the length of the trail allows it to be bent downwards under the breech without loss of strength, and so affords room for plain double-screw elevating gear in place of the somewhat complicated worm-wheel gear which was the weakest point of the author's 1904 design.

In view of the necessity for accurate fire at shielded guns the sight proposed for the 1904 design can no longer be considered satisfactory. Accuracy of direction is only possible with a sight pivoted parallel to the axis of the piece, so that it can be cross-levelled for difference of level of wheels. There are two constructions which satisfy this condition without sacrificing the advantages of the independent line of sight. One is the Krupp sight described on page 23; the other, which is, in the writer's opinion, a more serviceable construction, is Colonel Scott's "automatic" line of sight (Patented 1898).

This is similar in principle to the Krupp sight. The sight, which is of the rocking bar pattern, is on the cradle, and is pivoted parallel to the axis of the piece so that it can be cross-levelled. To counteract any movement of the sight when the gun and cradle are elevated, the sight is supported at the rear end on a cam connected to the intermediate carriage or to the centre of the double-ended elevating screw. When the gun and cradle are elevated this cam depresses the sight with respect to the cradle, and vice versâ, so that the line of sight remains directed on the object. The goniometric attachment is similar to that proposed in the 1904 design, except that the graduated circle is at the base of the pillar instead of at the top.

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APPENDIX.

THE EVOLUTION OF A FIELD GUN.

(1904.)

From time immemorial it has been the privilege of the regimental officer to grumble at the *matériel* supplied to him. No doubt the Greeks before Troy complained of the short range of the catapults and freely criticised the legs of the wooden horse.

Now sound criticism from the regimental officer is an excellent thing. It is only by correcting our shortcomings that we can make any progress towards perfection, and the gun-designer must always look to the practical gunner to point out the defects in his design.

If the regimental officers were all of the same opinion as regards the alterations and improvements to be carried out, the task of the designing and manufacturing departments would be comparatively easy. Unfortunately, however, a plébiscite of the Royal Regiment is apt to give rather vague and contradictory results. It is not so much that officers differ as to tactical requirements, but that the main issues are obscured by a mist of technical difficulties. This is especially the case as regards Q.F. field guns. Most officers at home have had an opportunity of seeing and handling modern guns; but for officers abroad the only means of keeping their knowledge up to date is the study of the occasional translations from foreign magazines which are published with the Journal of the Royal Artillery.

Moreover, the theory of construction of modern Q.F. guns, carriages and ammunition is a new science. No books have hitherto been written on the subject, and the rules of construction applicable to the older guns require considerable modification to bring them up to the level of modern science.

It is therefore not a matter for surprise that a large proportion of regimental officers have rather a vague idea of the construction of a Q.F. gun, of the qualities to be aimed at by the designer, and of the practical limitations by which designer and manufacturer are bound.

It may assist officers to form more definite views upon these points if we follow the design of an imaginary field gun, considering the difficulties of construction as they arise, and describing the methods devised by modern science to overcome these difficulties.

In dealing with such a subject it is difficult to avoid the temptation to attempt originality—to try for something never thought of before, which shall throw all previous inventions into the shade. But practical experience shows that such flights of imagination do not advance one very far. It is only once in a century that a genius like Marconi arises to upset all our preconceived notions of things possible. Improvements in guns and gunnery have so far been due to the gradual development and perfection of existing types.

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Moreover, even supposing it possible to originate a novel design of surpassing excellence, it would be open to the *primâ facie* objection that no one could predict whether the gun would work or not till it had been practically tried.

It is proposed, then, to keep strictly to the beaten track, and to describe an imaginary equipment of which every individual feature has already been practically tested and approved.

SPECIFICATION.

Let us suppose this such as to give the designer a free hand, and that the problem is merely to produce a powerful Q.F. gun of moderate weight. Then the easiest method will be to begin by designing a gun of sufficient power, then to calculate its weight, and finally, if necessary, to modify the design in order to bring the weight down to a practical figure.

THE CALIBRE.

For a given weight of shell, the smaller the calibre the higher will be the ballistic coefficient. But, on the other hand, the longer the shell the less will be the useful weight, *i.e.*, the proportion of the weight of the bullets to the total weight of the shell. And since after all a gun is merely a machine for delivering bullets at a given distant point, this last consideration is of great importance.

The choice of the calibre must therefore be of the nature of a compromise. There is a considerable weight of scientific opinion in favour of a 2.75″ calibre—the size originally proposed by General Wille in his "Field Gun of the Future"—but no successful 2.75″ gun has yet appeared, and all the Continental nations, besides America, have adopted a gun of about 75 mm. or 3″ calibre. We shall therefore be quite safe in accepting 3 inches as the calibre of our gun.

WEIGHT OF SHELL.

This is a comparatively simple matter; most modern 3″ guns have shrapnel weighing 14.3 to 14.7 lbs., and the American shrapnel weighs 15 lbs. The latter size gives a better shrapnel and better ballistics than the two former, but the recoil is necessarily greater. As however we do not propose to limit ourselves so strictly in the matter of weight as the modern German manufacturers, we may start with a 15-lb. shrapnel, subject to a possible reduction should the recoil prove too much for our carriage.

MUZZLE VELOCITY.

The object of a high muzzle velocity is not to increase the range of the gun, nor yet the remaining velocity; it is to decrease the angle of descent. The steeper the angle of descent, the less the distance which the shrapnel bullets will cover before they are stopped by striking the ground. Modern infantry tactics, and the Q.F. artillery tactics which have been devised to meet them, require the power of covering a large area with bullets without sacrificing intensity of effect; and this is most economically achieved by increasing the effective depth of the shrapnel cone without reducing the number of bullets or the angle of opening.

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The French gun is a good example of a successful combination of angle of opening and angle of descent. It is reported to have a M.V. of 1740 fs. with a 15.88 lb. shell. This, with an angle of opening of 16½°, gives at 3000 yards a cone 330 yards deep with a maximum width of 95 yards, containing some 250 (out of 300) effective bullets of 38 to the lb.

Since the ballistic coefficient of our shell will be somewhat inferior to that of the French shell, we will try a higher velocity, namely 1800 fs.

BALLISTICS.

We can now lay down the ballistic elements of our gun. Assuming a shell with 2-diameter head, we shall have a range of 6000 yards with 11° 44′ elevation, 7,600 with 18°, and 8,000 with 20° 10′. The angle of descent will be 4° 8′ at 2,500 and 7° 56′ at 3,500 yards; the angle of opening of the shrapnel at 3,500 yards will be about 17°. The muzzle energy will be 337 foot-tons.

THE GUN.

We have next to design a gun to give the required ballistics.

There are two ways of getting a high M.V. out of a gun—one is to increase the length, and the other to increase the powder charge. The former is by far the most satisfactory method, as involving less strain and less waste of powder. Let us see what precedent we can find to guide us as to the length of the gun.

The Elswick Field Battery in South Africa were equipped with the "Lady Meux" gun, 130 inches long. They took these guns throughout the war, and marched several thousand miles with them. One gun covered 2,300 miles in 15 months. No objection was ever made to the long muzzle.

On the other hand, the average length of modern guns is considerably less than this, 92 inches being about an average.

Now calculation shows that if we take the pressure in the chamber at 15 tons (the usual amount for a field gun) then to get 1,800 fs. the bore will have to be 32 calibres long, giving a total length of 102 inches. This is a moderate length and may be accepted as suitable.

This gun will require nearly 20 oz. of cordite, Mark I., size 10, occupying 82 cubic inches. Cordite burns better in a short chamber than in a long one, and if we adopt a coned chamber 4″ in diameter at the base and 10″ long, it will hold the charge comfortably.

If tubular cordite be used the pressure in the chamber will be slightly less and the ignition possibly more regular.

WEIGHT OF GUN.

The weight of the gun may be determined by comparison with approved models. Thus the Ehrhardt 15-pr. Q.F. gun weighs 737 lbs.; add 45 lbs. for lengthening the muzzle 12 inches, and we have 782 lbs. The increase of strain due to the larger powder chamber may be met by adopting the R.G.F. wire construction instead of the simple Ehrhardt two-layer build, while the abolition of the chase rings used on the original model will enable the diameter of the gun to be increased from 8″ to 8.25″ without increase of weight.

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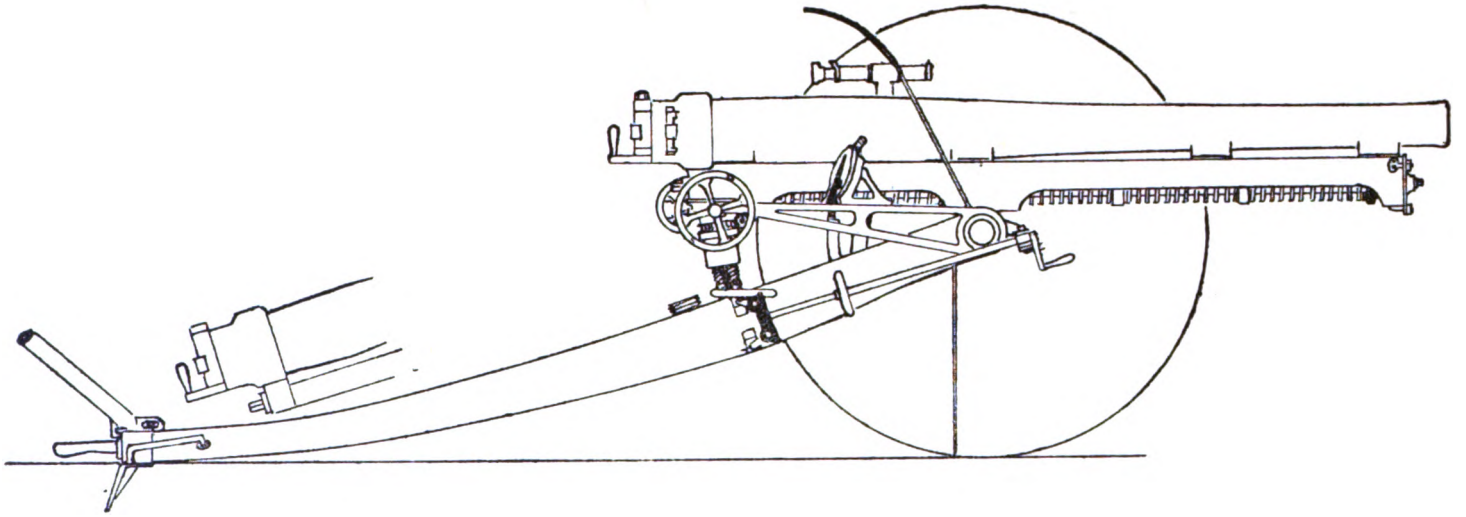

FIG. 1.

15-pr. Q.F. Gun, M.V. 1,800 fs. Scale: ½ inch to a foot.

Fig. 1 shews the gun viewed from the right side; the support for shield is omitted to avoid confusing the drawing. The gun is intended to have a preponderance of 28 lb. Owing to the complicated shape of the parts it is difficult to calculate the exact position of the gun for a given preponderance, but the drawing is correct within an inch or so. But with a cradle affording a bearing for the gun 7′ 6″ long, considerable latitude is permissible, and the gun may be shifted three inches or even six inches either way without affecting the rest of the design.

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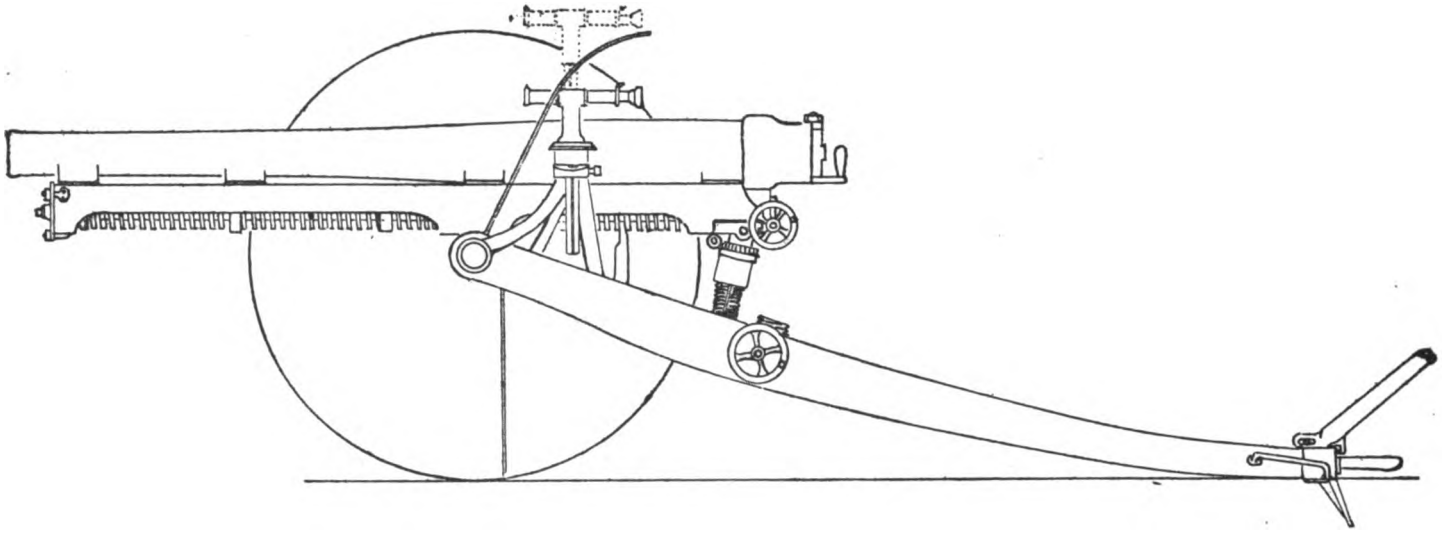

FIG. 2.

15-pr. Q.F. Gun. View from left side.

Fig. 2 shews the gun from the left side. The brake arm, seat, shield-stay, and stay connecting traversing bed with axletree are omitted for the sake of simplicity. The layer's seat is on the brake arm and is supported like a music stool upon a screw which enables the layer to adjust its height so that the telescope is convenient to his eye. This is an Ehrhardt arrangement. The firing lever is not shewn; it is placed conveniently to the layer's left hand, and works a trigger in the face of the breech which cocks and releases the trip-lock in the breech block. If the gun fails to run up completely, the firing lever will still act so long as the gun is not more than two inches short of its proper position. Under the breech is a locking catch; when the gun is at maximum elevation, with the cradle right down on the trail, this catch may be secured, locking the laying and elevating gear so as to prevent any strain upon them in travelling.

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RIFLING.

The determination of the best pitch of rifling for a given shell is not yet, unfortunately, a matter of exact science. But the pitch adopted for the new American 15-pr. is one which has given excellent results, namely a twist increasing from 1 in 50 at the breech to 1 in 25 calibres at the muzzle.*

MATERIAL.

All modern guns are made of nickel steel, containing 3 to 6% of nickel, and having a tensile strength of about 50 tons to the square inch.

BREECH ACTION.

Both the wedge and the eccentric screw are simple, strong and durable. But the latest model of swinging block is more powerful in loading and extracting than either of these, and consequently less liable to jams. This action (which has been adopted in our own Q.F. equipment and in the American gun) has a single-motion cylindrical swinging breech-block. It is set about $\frac{1}{4}$" eccentric to the gun, so that when the breech is closed the striker is not opposite to the cap in the cartridge till the block has been turned through a right angle to lock it. This forms an efficient safeguard against prematures occurring in closing the breech.

The firing action is a trip-lock, in which the layer, by pulling the firing lever, first draws back the striker and then releases it.

The extractor grips the cartridge both above and below, and is actuated by the breech block, which at the end of its swing strikes the outer end of the extractor and so causes the inner end to jerk out the cartridge.

RECOIL GEAR.

The hydraulic buffer is well established as an efficient means of checking recoil. It consists of a cylinder 2.75" in outside diameter, and 0.3" thick, attached by a horn to the breech of the gun. In this works a piston, the front end of the piston-rod being attached to the carriage. When the gun recoils, the cylinder is drawn back and the oil or glycerine in the cylinder is forced to flow through the narrow space or windage between piston and cylinder, formed by the grooves or ports in the inner wall of the cylinder, thus gradually checking the recoil. The depth of these ports is slightly different at different points so as to keep the pull on the piston rod proportional to the varying stability of the carriage throughout the recoil.

Boring a buffer for uniform stability is a delicate operation, as a difference of a couple of hundredths of an inch is found to make all the difference between a steady gun and one which kicks like a mule. The correct depth of the ports at each point is determined by the use of the buffer gauge, first introduced by the Elswick Ordnance Company.

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* NOTE.—The 1906-07 fashions in gun-designing favour the uniform twist. See page 26.

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This is a pressure gauge communicating with the inside of the buffer through a hollow piston-rod, with an indicator which, as the gun recoils, traces a line on the smoked surface of a strip of metal attached to the gun. If the pressure is correctly regulated, the line is a curve parallel to the curve of stability. If it is not, the boring of the buffer must be adjusted accordingly.

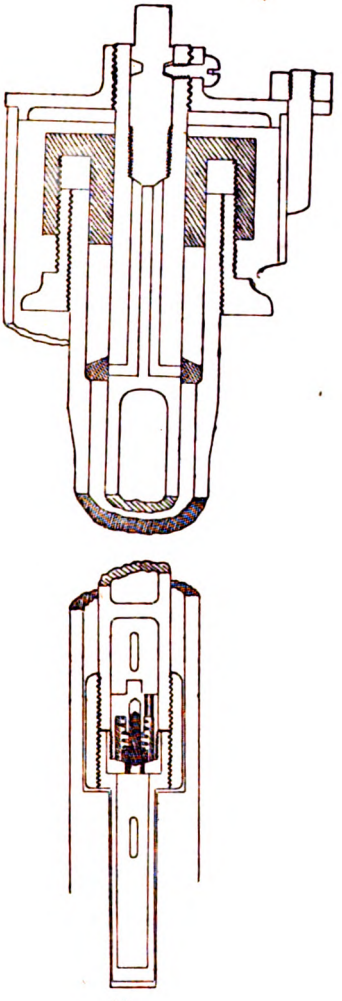

FIG. 3.
Running-up Valve & Buffer Gland.
½ size.

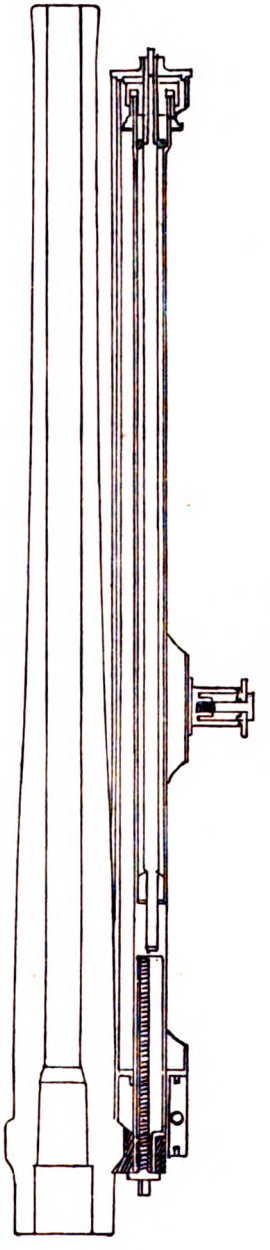

FIG. 7.
Section of Gun and Buffer. Scale 3/4" to a foot.

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LENGTH OF RECOIL.

Modern Continental guns have usually a working recoil of 1¼ mètre or 50 inches. As the M.V. chosen is unusually high, we may take a minimum recoil of 4 feet 6 inches, and maximum permissible recoil of 5 feet. The considerations which justify us in accepting this as sufficient will be discussed under the head of steadiness.

DETAILS OF BUFFER.

These are shown in Figs. 3 and 7, and are mostly copied from the Krupp 1904 equipment. Attention is called to the loose bottom of the stuffing box.

BUFFER LIQUID.

Either oil or glycerine may be used, the buffer being bored to suit. The writer prefers glycerine, as, although it is more difficult to obtain on service, it is more viscous and less subject to leakage through the gland.

RUNNING-UP VALVE.

This is a speciality of Ehrhardt's. In order to make the gun run up smartly after recoil, strong springs have to be used to overcome the buffer resistance. But if a valve be inserted in the piston to allow the glycerine to pass freely during running-up, the springs may be much thinner and lighter. No details of the Ehrhardt valve are available, but a suitable arrangement is shown in Fig. 3.

A second disc-valve on the end of the piston is rotated by rifled grooves in the buffer and gradually cuts off access to the running-up valve as the gun returns towards the firing position, thus bringing it gently to a standstill.

RUNNING-UP SPRINGS.

The column of springs cannot without undue increase of weight be made more than about 6 feet 6 inches long. But if the gun is to recoil 4 feet 6 inches, this means that the springs must be compressed into a space of 2 feet each time. For some years it was believed that springs could not be made to stand this treatment, and telescopic spring-cases were used, with a double column of springs, which practically halved the compression. But it is now found that flat springs of suitable section will stand compression to one-quarter of their length (in addition to the initial compression) without injury. The light springs which the running-up valve enables us to use give no trouble in this respect.

Accordingly, in the Krupp gun we find the springs compressed to one-quarter of their length. To be on the safe side we will only require our springs to stand compression from 6 feet 6 inches to 2 feet, or about one-third of their length. This arrangement is shown in Fig. 7.

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THE CRADLE.

Since the buffer must be parallel to the gun whatever angle the latter makes with the main carriage, the gun and the buffer must be connected by a cradle, provided with slides for the gun and with a trunnion or trunnions which connect it to the carriage. (The only exception to this practice is found in the 1900 Russian gun, in which the buffer is parallel to the trail, not to the gun). The buffer is sometimes placed on top of the cradle, as in the English equipments. In these guns the cradle has horizontal trunnions and is mounted on an intermediate carriage, capable of traversing horizontally upon the main carriage.

A more usual construction is to put the buffer under the gun and to mount the gun on a slide on top of the cradle. This arrangement is adopted in the French gun, the American gun and by all Continental gun-makers. The new German gun is also of this pattern. A dissertation on the relative merits of the two systems would here be out of place; but it may be said that the advocates of the carriage with buffer under the gun claim lightness, simplicity and durability for their system, while the advocates of the top buffer claim to get the gun six inches lower than is possible with the other method.

Following our plan of choosing the easiest and most frequented path, we will select the system with buffer under the gun as most suitable for our present design.

The pattern of cradle chosen is that brought out by Messrs. Ehrhardt and modified by Krupp. This is a drawn steel tube containing the buffer and springs, of the section shown in Fig. 5. The

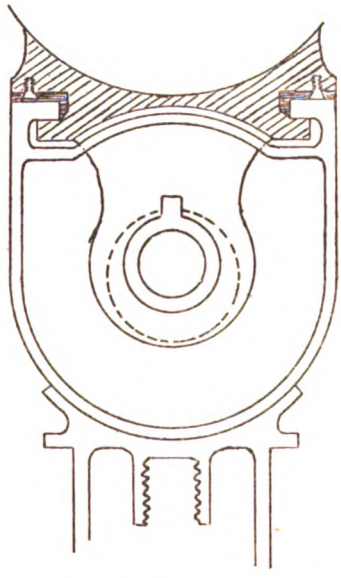

FIG. 5.
The Cradle. ¼ size.

gun slides along the top edges of the cradle, steel blocks being formed on the outer tube of the gun for the purpose. These blocks are faced with bronze to reduce friction.

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Messrs. Krupp, in one of their designs, modified the Ehrhardt cradle by cutting away the lower part so as to expose the springs. They claim that this not only saves weight but reduces the chance of the gear being jammed by a bullet indenting the spring-case. It is considered that a bullet striking the spring would not be likely to break it.

TRAVERSING GEAR.

In the French gun the gun, cradle, and trail traverse together along the axletree. This plan has the advantage that the recoil is always in line with the centre of the spade, so that the carriage does not tend to shift on firing. On the other hand, the weight to be moved is considerable, and, to prevent the wheels from shifting instead of the gun when the traversing gear is worked, special brake-shoes with fins have to be used under the wheels, which means delay in coming into action or in changing target.

We need therefore have no hesitation about adopting the central pivot method. For this, when a cradle under the gun is used, the cradle is pivoted with a single vertical trunnion either in a saddle pivoted horizontally between the trail brackets, or on the axletree itself. The latter system has both advantages and disadvantages. It means that when the gun is elevated or depressed the axletree has to turn with it, and consequently that the trail must be attached to the axletree with cap-squares, so as to allow the axletree to revolve. On the other hand, the system does away with the intermediate carriage and its trunnions, and allows the traversing bed to be rigidly connected to the axletree, giving a strong and simple construction. The actual traversing gear is quite simple, consisting of a hand-wheel and worm at the rear end of the cradle, gearing with a toothed segment formed on the traversing-bed, and allowing a traverse of 5° either way.

THE WHEELS.

Here we have an excellent pattern ready to hand in the Woolwich double-spoked 35B pattern, which has been thoroughly tested in South Africa. The diameter of the wheel is however a matter requiring consideration. The lower the wheel, the shorter the trail and the less the weight of the gun-carriage. On the other hand, small wheels mean heavy draught and reduced freedom of movement across country.

Most foreign equipments have 4 ft. 3 in. wheels; the American wheel is 4 ft. 8 in. English gunners have hitherto been accustomed to 5 ft. wheels. For the purpose of the present design, we may compromise on the 4 ft. 8 in. wheel, with the reservation that if the resulting weight of the carriage turns out to be excessive we shall have to reduce the size of the wheel.

THE TRAIL.

The French gun, which is perfectly steady on discharge, has a trail angle of 1 in 4. This, with a wheel of 2′ 4″ radius, would make our trail 9′ 4″ long. As however we hope to get the gun lower on the carriage than the French gun, we may try a somewhat shorter trail,

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namely 9 ft. on the ground line. This is about the same as the Krupp trail, but a good deal short of the length considered necessary by Ehrhardt and by the Americans, who use a 10′ 6″ trail.

The profile of the trail is such as to give 1″ clearance under the gun at full recoil and at the maximum elevation, 17°. This necessitates the trail being bent at the lower end. This feature may be noticed in several guns, as in the Cockerill and St. Chamond equipments. The trail is formed as a U-shaped trough of 0.25″ steel plate with the upper edges turned in; the rear portion is stiffened by a light steel top-plate, and there is a sole plate to protect it from injury on hard ground. The trail is open top and bottom forward of the elevating gear, where it is strengthened by a ring forging at top, which also carries the guides for the laying block. Forward of this the trail forms two brackets, which are splayed 14 inches apart so as to allow the arm carrying the telescope, and the arc which controls the range-dial, to clear the gun at maximum traverse. The brackets are attached to the axletree by capsquares as in the Ehrhardt equipment.

STEADINESS.

We can now consider whether the proposed gun will be steady on discharge. The calculation of the overturning strain is not quite a simple matter, being complicated by cross-strains in the carriage. Broadly speaking, the higher the axis of the gun the greater will be the overturning moment. The position of the point of attachment of the buffer to the carriage has considerable influence on the result. But in this case, since the buffer is below the gun, we shall have something in hand if we take the overturning strain as acting through the axis of the gun. For with the buffer under the gun the centre of gravity of the recoiling parts, through which the force of recoil must be assumed to act, is below the axis of the gun.

Assume that the whole system pivots about the centre of the spade, 3″ below the ground line. Then on the one hand we shall have the force of recoil acting through the axis of the gun, and tending to turn the gun over backwards; on the other hand the weight of the gun and carriage acting through the centre of gravity and tending to keep the wheels on the ground.

Now the M.V. being 1800 fs. and weight of shell 15 lbs., the muzzle energy in foot-lbs. is:—

$$\frac{15 \times 1800^2}{2 \times 32.2}$$

or 337 foot-tons.

The weight of the gun is 782 lbs.; weight of buffer (which recoils with it) 79 lbs., and half the weight of springs 35 lbs., total 896 lbs. The weight of the shell is 15 lbs., that of the charge 20 oz.

The ordinary recoil formula is:—

$$WU = (w + Cw_1)\,V$$

where C, the coefficient for the increase of recoil due to muzzle blast, is taken at 1½. Putting the above values in the formula, we get:—

$$U = 33.9 \text{ fs.}$$

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whence the recoil energy is:—

$$\frac{896 \times 33.9^2}{2g \times 2240}$$

or 7.142 foot-tons.

Since the recoil-energy is absorbed during a recoil of 4½ feet, we have an average pull on the buffer-rod of:—

$$\frac{7.142}{4.5} \text{ tons.}$$

or 1.587 tons.

The height of the axis being 41 inches, or 44 inches above the centre of the spade, we have, when the gun is fired without elevation, a force of 1.587 tons acting at the end of a 44-inch lever tending to overturn it. This force is resisted by the weight of the gun and carriage, which we may estimate provisionally at one ton, acting through the centre of gravity about 7′ 6″ from the spade.*

Then we have an overturning force of

$$\frac{1.587 \times 20 \times 44}{12} = 116.4 \text{ cwt.}$$

against

$$1 \times 7.5 \times 20 = 150 \text{ cwt.}$$

Therefore, assuming the boring of the buffer to be perfect, we have some stability in hand even when firing without elevation. As the elevation is increased the leverage of the gun decreases and the stability increases, so that a well-designed carriage tends to "squat" or sink into the ground at each shot.

The above calculation does not take into account the elastic rebound of the carriage, due principally to the spring of the trail under the pressure of the elevating screw. In modern Continental equipments it is customary to allow 5 cwt. or 6 cwt. of surplus steadying weight on this account. We have only allowed

$$\frac{150 - 116}{7.5}$$

or 4.5 cwt. But it should be said that, in Germany especially, there is a tendency rather to exaggerate steadiness at the expense of power. The cult of steadiness has degenerated towards a rather flat-catching form of advertisement, and German makers proudly announce that their gun will put 12 rounds of rapid fire into a target without relaying. This is all very well, but the Battery Commander does not want to fire his guns without relaying, except at "Cavalry attack." It is sufficient for practical purposes if the deviation is so slight that the layer is able to correct it during the time available—say three seconds—between the rounds.

* The calculation is not really so simple as this, since the centre of gravity shifts as the gun recoils, and the buffer-resistance has to be adjusted accordingly. But for a preliminary estimate it is sufficient to take the mean position of the centre of gravity. Strictly speaking, instead of the height of the axis we should take the height of the centre of gravity of the recoiling parts.

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We may take it, then, that the present design will fulfil practical requirements as to steadiness. To obtain a higher degree of steadiness with the proposed muzzle-energy we must either increase the weight of the gun, or reduce the size of the wheels, or increase the length of the trail. And none of these three alternatives commends itself to the regimental officer.

LAYING AND ELEVATING GEAR.

No modern Q.F. gun is complete without the "independent line of sight." This means that the laying number works a wheel which elevates the gun and sights together till the sights bear on the target, while the elevating number, on the other side of the gun, works another wheel which gives the gun the elevation above the line of sight required for the range, without affecting the sights. The amount of elevation given is shown on a dial.

This arrangement greatly facilitates the service of the gun, and we need have no hesitation in embodying it in the present design.

RANGE OF ELEVATION.

The long-trail equipments at present in existence, as the Ehrhardt and the American guns, have one serious disadvantage, namely the limited amount of elevation that can be given. This works out as follows:

Suppose the gun brought into action on a 3° forward slope, at a target 3° above the battery. Then for the first round, before the spade has sunk into the ground, the point of the trail will be another 3° above the normal level, making a total deduction of 9° from the elevation allowed by the carriage. That is, if the carriage affords no more than 15° of elevation, we shall only be able to put on 6° for the first round. This evil is reduced in the present design by the increased muzzle velocity, which requires less elevation for a given range. But even so the usual 15° is insufficient, and provision is therefore made for giving 17°. This, in the above combination of unfavourable circumstances, will still give a possible elevation of 80° or 4,800 yards nearly for the first round.*

No depression is required, since the gun is never layed below the line of sight. If the target is below the battery the necessary depression is given by the laying gear, not by the elevating gear.

With the laying gear we require to point the sights at a target 3° above the battery, when the gun is on a forward slope of 3°, and before the spade has sunk in. We may also require to point the sights at a target 3° below the battery, from a reverse slope of 5°. Therefore we shall require a range of at least 17° from the laying gear.

* The Japanese field gun, which was built for rough mountain country, has a range of elevation and depression of 25 degrees.

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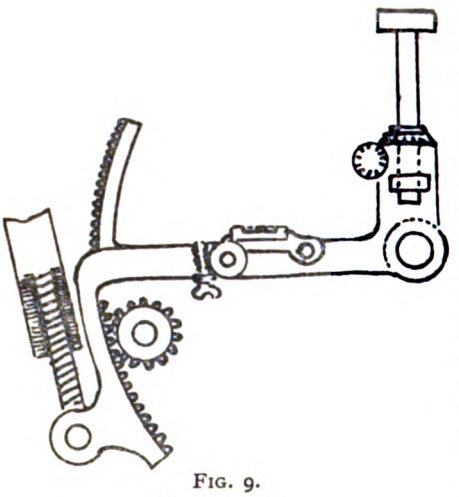

FIG. 9.
French Gear.

The principle of the laying and elevating gear is adapted from the French gear, which, apart from the traversing arrangement, has proved a conspicuous success. Part of the French gear is shown in Fig. 9, and it will be seen that the gear sketched in Fig. 10 is on the same principle. It will be seen that the French gear consists of a radius bar which carries the sight standard and clinometer, pivoted on the same centre as the trunnions of the cradle. The rear end of the bar is raised and lowered by a pinion worked by the laying wheel, which gears into a toothed arc on the bar. The elevating screw is stepped at the rear end of the bar, which thus answers the purpose of an intermediate carriage.

Now, when we attempt to use this device in our design, we find that a toothed arc of 17° sticks out either above the trail, where it would foul the gun during recoil at extreme elevation, or below the trail, where it would be smashed in driving over a bank. We must have something more compact. Mechanical science affords many ways of effecting this; the one preferred is sketched in Fig 10 and shown in detail in Fig. 4.

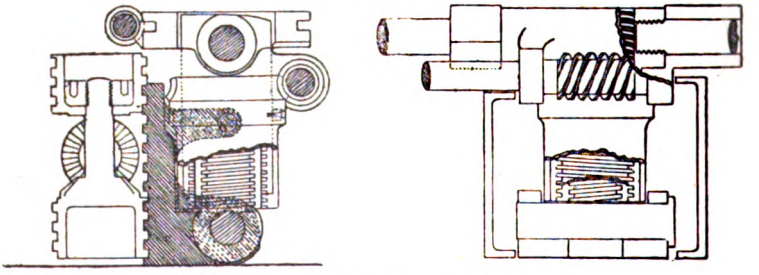

FIG. 4.
Laying Screw and Elevating Screw.—1/8 Size.

Fig. 4 shews the laying and elevating screws. The double elevating screw screws into a socket which supports the traversing bed, and so the rear end of the cradle. This is the same as the French arrangement, except that the latter has no traversing bed. The outer screw is turned by a sheath surrounding the socket, with two projections which engage in longitudinal slots cut in the outer screw, as in the 15-pr. B.L. elevating gear. The sheath is held in place by a ring sprung into a recess in the sheath and screwed (through a hole in the sheath) to the socket. The sheath is turned by a triple-threaded worm; the worm-shaft is revolved by a pinion gearing with an inside-toothed wheel at the back of the elevating wheel. A more direct

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gear would be a pair of bevel wheels instead of the worm. But to get 17° of elevation we have to use every inch of space between the breech and the trail, and it is not easy to find room for a pair of bevel wheels. Room might be made by bending the trail downwards, but this means either loss of rigidity or increased weight.*

In Fig. 10 we have a block, known as the laying block, working in guides between the trail brackets, moved up and down by a screw

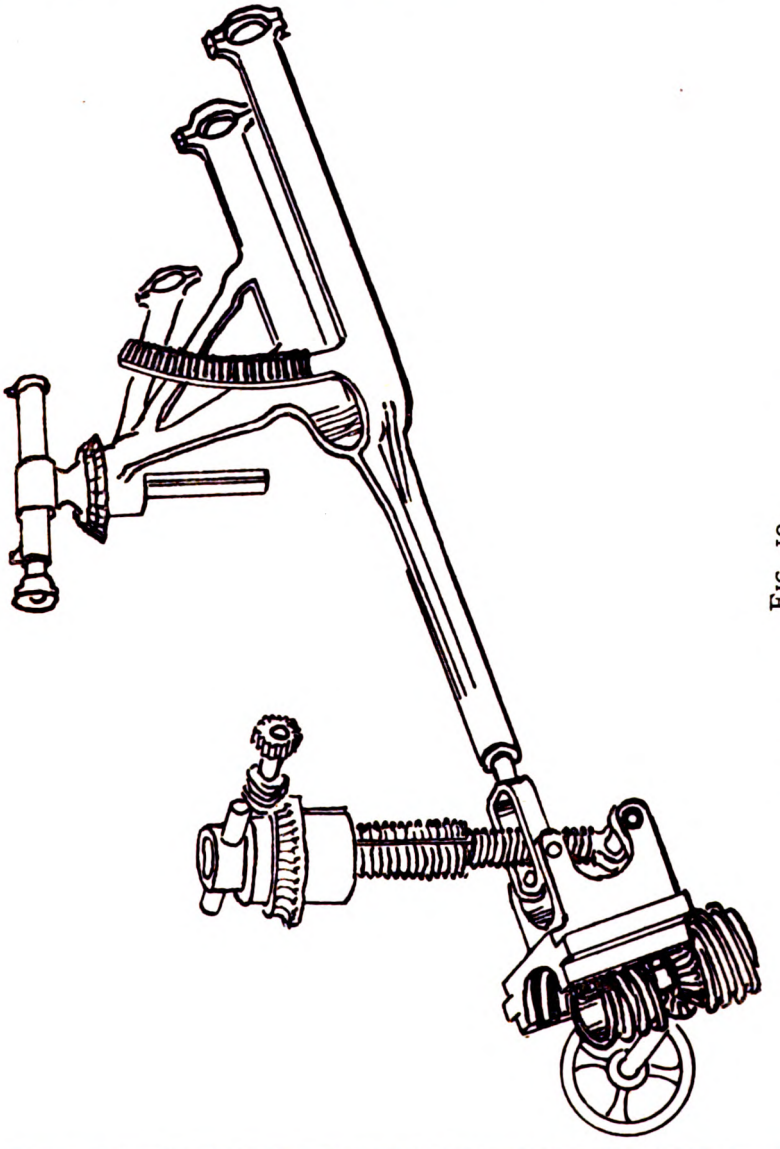

FIG. 10.
Sketch of Laying and Elevating Gear.

* NOTE.—On re-consideration, the author would prefer a bent trail and a simpler elevating gear. (1907.)

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which engages with its rear face. The screw is hollow, 4 inches in diameter, and 8½ in. long, which gives us room to cut away 3½ inches in the centre for a pair of 3″ mitre wheels to turn it, and still have 2¼ inches of screw engaging with the block in the extreme highest and lowest positions.

The rear end of the radius bar is pivoted to the block. But since the bar moves in an arc and the block in a straight line, the joint between them must allow of a small amount of longitudinal movement. At first sight this might appear to introduce an error in elevation, since the block does not move through quite the same angle as the gun. But this error is eliminated, as will be seen afterwards.

The radius bar is of steel, of such a form as to be as rigid as possible in a vertical plane. Its front end embraces the axletree on either side of the vertical trunnion. It is not however pivoted directly upon the axletree, but upon a bronze sleeve on each side, surrounding the axletree and tightly gripped by the trail, so as to turn with the trail. The effect of this is that the accuracy of the pivoting is not affected by wear between axletree and radius bar, and the extent of motion of the joint is limited to that between radius bar and trail, which is only that due to the angle of sight. Moreover the telescope is saved from direct shock due to the vibration of the axletree in travelling.

The radius bar carries the telescopic standard on one side, and the toothed arc which works the elevating dial on the other. Owing to the small space left by the traverse of the gun, it is only possible (without unduly increasing the width of the trail) to make the pedestal rigid in a fore-and-aft direction. Lateral rigidity has to be provided by a side stay pivoted on an extension of the axletree sleeve already referred to. *See* Fig. 15.

TRAVERSE OF SIGHTS.

In the French equipment, when the gun is traversed the trail, cradle and sights move with it. But in the present design we have discarded this feature, and the traversing gear is applied to the gun itself, not to the trail.

It is therefore necessary to provide some arrangement for making the sights traverse with the gun. For the sights and the gun must move together, in order that the gun may always point in the same direction (barring deflection) as the sights.

In one of the Ehrhardt field howitzer equipments this motion is provided for by connecting the vertical pivot of the sight bar to the vertical trunnion of the cradle by a bicycle chain, so that sight and howitzer revolve together through equal angles. Several other mechanical devices may be used for the same purpose, such as the connecting rod, or crossed links. But probably the simplest and most compact gear is that shewn in Fig. 15.

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The telescope socket, which carries the divided circle and the telescope with its base-plate, is capable of revolving in the pedestal. An arm projects from the socket towards the gun, terminating in a roller working in a cam-groove in the traversing plate *A*. This plate traverses right and left with the gun, and the cam groove is so cut that as the plate traverses it moves the arm, and so the telescope, through the same angle as the gun. The traversing plate is supported in a guide carried by the radius bar, which also carries the telescope pedestal.

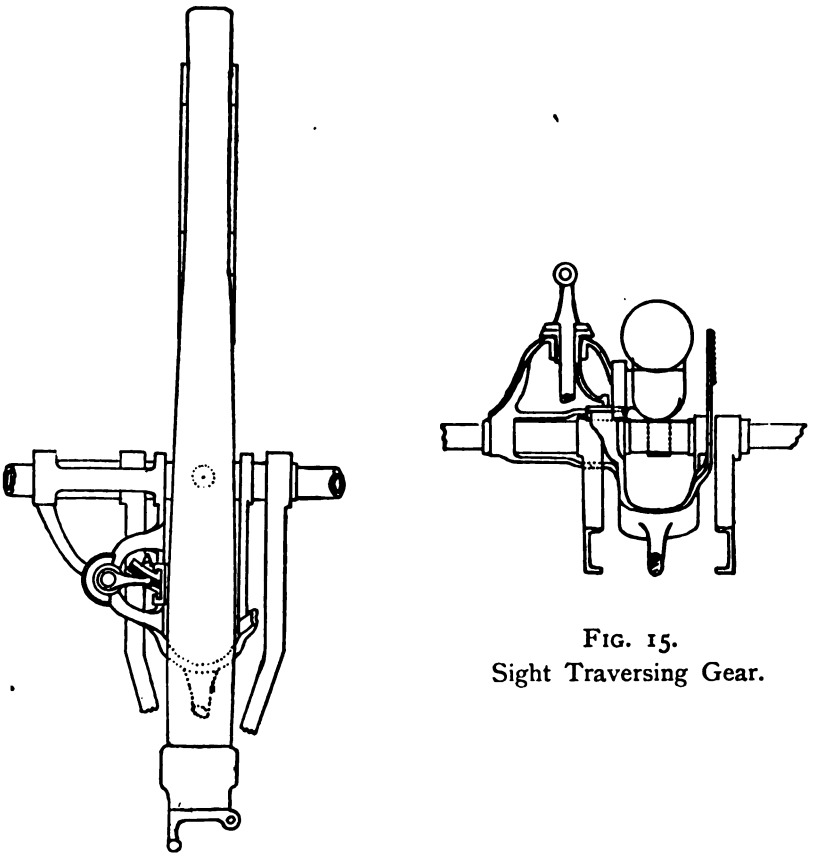

FIG. 15.
Sight Traversing Gear.

To enable the gun to be elevated and depressed freely without affecting the traversing plate, the latter is not rigidly attached to the gun or cradle but works in a circular guide on the side of the cradle, struck from the centre of the axletree.

THE ELEVATING GEAR.

This is of the familiar double-screw pattern. The inner screw is stepped on a pivot in the laying block; it is surrounded by the outer screw, which again screws into the socket pivoted to the traversing

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platform. The outer screw is slotted to receive two projections on the lower edge of the sheath which surrounds the socket, so that when the sheath is turned by a worm wheel the outer screw is rotated, screwing itself off the inner screw and out of the socket simultaneously.

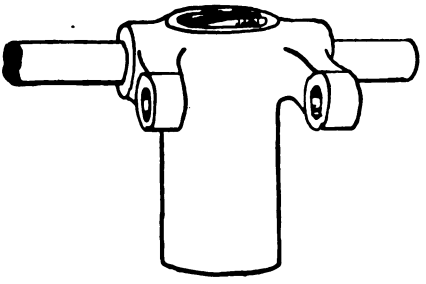

FIG. 8.
Sketch of Elevating Screw Socket.

No part of the gear may project below the trail, so the space into which the screws must pack is limited. To make the most of the space, both screws are carried up right through the socket, which again goes up through the centre of the traversing platform; and the traversing platform itself is bedded not under the rear of the spring-case, but close up under the buffer. This arrangement shortens the spring-case by 3½ inches at the rear end, which amount has to be added at the fore-end of the cradle; but this drawback may be put up with for the sake of keeping all the gear above the level of the bottom of the trail.

The sheath which turns the elevating screw is revolved by a worm wheel carried in bearings on the socket. The outer end of the worm spindle carries a spur wheel which gears into teeth cut inside the back of the elevating wheel; the latter rides on the continuation of one of the trunnions of the traversing bed. A small link on the same trunnion supports the outer end of the worm spindle and keeps the gears correctly in mesh.

The elevating screws have three threads to an inch; the worm wheel has 30 teeth, and the worm is triple-threaded. The gear between elevating wheel and pinion is 5 to 1. The effect is to raise the breech one-third of an inch for every turn of the hand-wheel, so that 36 turns are required to move the gun from maximum elevation to the horizontal position. This is rather a slow gear, but, with a 10-inch elevating wheel, should be a smooth and powerful one. It allows a 28-lb. preponderance, which prevents any possibility of play in the elevating screws.

THE TRAVERSING BED.

This is a steel block carried on trunnions on the head of the elevating screw socket. The block is rigidly stayed to the axle (which moves with it, as will be remembered) by the bracket stay shown in Fig. 1 on the right side, and by a tubular stay to the shoulder of the axletree on the left. The traversing platform supports the traversing plate at the rear end of the cradle. The traversing worm, spindle, and hand-wheel are carried on the cradle and traverse with it.

THE RANGE DIAL.

This is carried on the bracket stay on the right of the gun, and faces so that it can be read by the No. 1 from the end of the trail.

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The dial is of ideal simplicity, consisting of only two pieces, besides the shifting fuze-scale. It is worked by a toothed arc (which is really a portion of a large bevelled wheel) carried by the radius bar, which arc engages with a bevel wheel formed on the back of the dial.

It will be seen that this arrangement does away with any error which may arise from inaccuracy in the working of the laying or elevating gear. If the dial were connected by gearing to the elevating hand-wheel, any error due to play, wear, or backlash in the gear would be transmitted to the dial. As it is, the motion of the dial is governed by the relative motion of the bracket arm which carries it, which moves with the gun, and the radius bar, which carries the sighting telescope. Thus the dial always measures the true angle between the axis of the piece and the line of sight, quite independently of the action of the elevating and laying screws. In fact, so far as the dial is concerned, its action would not be affected if the elevating were done with handspikes and quoin.

THE SIGHT.

The sighting telescope is fixed as high as is possible consistently with rigidity. The object of a high line of sight is to be able to fire from behind a crest without undue exposure. Thus, in the design the telescope is 4 ft. above the ground; this enables the gun to be run back till only 8 inches of the top of the shield shows over the crest, while the layer is still able to see the target.

For indirect laying the telescope must be capable of being directed at an aiming point to a flank or to the rear. For this purpose it is made to draw out of its socket till it is above the level of the wheels. A graduated base-plate measures the angle between aiming point and target. This base-plate is exactly similar to that on the battery director, except that it has in addition a tangent screw reading to five minutes for giving deflection.

The telescope is so placed that it passes through the shield near its vertical axis. This allows the hole in the shield to be but little larger than the telescope. A slit in the shield, covered by a flap door, allows the telescope to be raised to the high position.

The telescope itself is an erecting telescope magnifying about five diameters; it has a field of 6° with a horizontal pointer. It is about one foot long, with an object-glass 1¼ inches in diameter. No open sights are provided except a foresight and backsight on the telescope for quick laying at close quarters.

For travelling, the telescope with its stem is drawn out of the socket and carried in a padded case at the back of the shield.

The clinometer is of the arc pattern, attached to the telescope socket; it is set low down for convenience of reading.

DEFECTS OF PROPOSED SIGHT.

The sighting arrangement described above, which is copied in principle from the French sight, is simple and efficient. It has however two essential drawbacks.

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In the first place it does not automatically correct for drift. In equipments with an intermediate carriage it is possible to incline the trunnions of the cradle to an angle equal to the mean angle of drift; but in this design the horizontal pivot is the axletree itself, and this method is not applicable. With the independent line of sight there is of course no tangent scale to set at an angle. Compensating gear to correct for drift might be added, but the result would hardly be worth the complication. Accordingly, the correction for drift must be read off on the deflection corrector described below, and given by the layer on the base-plate of the telescope.

In the next place, the proposed sight is not a "reciprocating" one. The telescope is not supported on the cradle, which is parallel to the gun, but upon the radius bar, which is not. No amount of inclining the vertical support of the telescope would compensate for one wheel being higher than the other.

At ordinary targets it will not be necessary to correct for difference of level of wheels. But when firing at a shielded gun accuracy of direction is essential. Accordingly a "deflection corrector" is fixed to the back of the shield in front of the layer. This device is shown in principle in the diagram, Fig. 14. It consists of a pivoted level

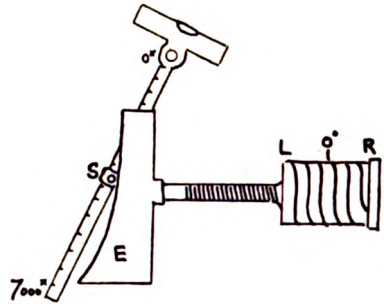

FIG. 14.
DEFLECTION CORRECTOR.

with a long stem, graduated in yards of range or (more correctly) in degrees of quadrant elevation. A stud *S* can be shifted up and down the graduated stem, and is pressed by a spring against the edge of the plate *E*, which is traversed by a drum spirally graduated in degrees and minutes of deflection. It will be seen from the figure that the greater the elevation the more turns have to be given to the drum to bring the bubble to the centre.

The edge of the plate *E* is not straight, but is curved to the curve of drift, so that the reading on the drum gives the combined deflection due to drift and difference of level of wheels.

So far as the writer is aware, this instrument is a novelty. There is however nothing new in the mechanism, which is imitated from the Watkin rangefinder.

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It will be seen that by abandoning the old tangent scale or arc scale in favour of the range dial and independent line of sight we sacrifice the possibility of automatically correcting for difference of level of wheels by levelling the back-sight. For Field Artillery, however, this drawback is far outweighed by the advantage of relieving the layer of all concern about the elevation.

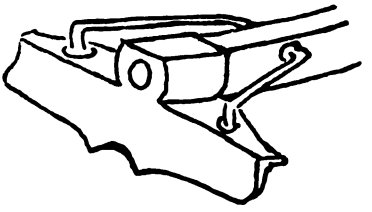

FIG. 16.
SPADE.

THE SPADE.

This is similar to the spade on the 15-pr. Q.F. (Ehrhardt) gun, which has been found to act remarkably well. It has however two points instead of one (*see* sketch, Fig. 16) which reduces the amount of downward projection. The spade is set 18° from the vertical; this angle has been found suitable for a 9-feet trail.

THE BRAKE GEAR.

This is of the pattern hitherto used in almost all modern guns. It is a combined firing and travelling brake, consisting of two brake blocks attached to arms pivoted to the trail. Tension rods attached to the blocks are fixed to a crossbar pivoted to the trail in front of the axletree. The effect of this is that if either tension rod is shortened by a screw both brake blocks are applied to the tires. The brake can be actuated from the front or from the rear of the shield, and has a quick release action (not shown) which enables it to be thrown off without unscrewing it.

It should be noted, however, that in some of the latest field guns there is a tendency to discard the firing brake as useless. Thus the American gun has a simple travelling brake, of the pattern now known as South African, applied to the wheels under the muzzle.

THE SHIELD.

Most Continental nations are adopting a shield either from 3 to 5 millimetres thick, calculated to keep out shrapnel bullets altogether and to stop infantry bullets at 200 to 300 yards. The Americans have adopted a 5-millimetre shield, which is practically bullet proof at all ranges. We may safely take a medium figure, 3½ millimetres or 0.14 inch. This thickness weighs about 6 lbs. to the square foot, so that the shield in the design, which is 22.5 square feet in area, will weigh 135 lbs. net without supports and attachments. Foreign makers usually leave the shield without any rim or edging. But in deference to English ideas of solidity we may add a small angle-steel rim at the sides only, leaving the top a plain edge.

Shields are made of nickel-chrome or nickel-tungsten steel. Thus the Ehrhardt shield and the American shield are made of steel with a tensile strength of 105 tons to the square inch.

Nickel-chrome steel will probably be superseded before long by vanadium steel, which is much harder and tougher. But this metal is at present too expensive for ordinary use.

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The upper part of the shield is hinged to the axletree and is supported by tubular stays bolted to the trail, as in Fig. 11. A disc of compressed felt is placed on either side of the shield at the point of attachment of the stay; this reduces vibration in travelling.

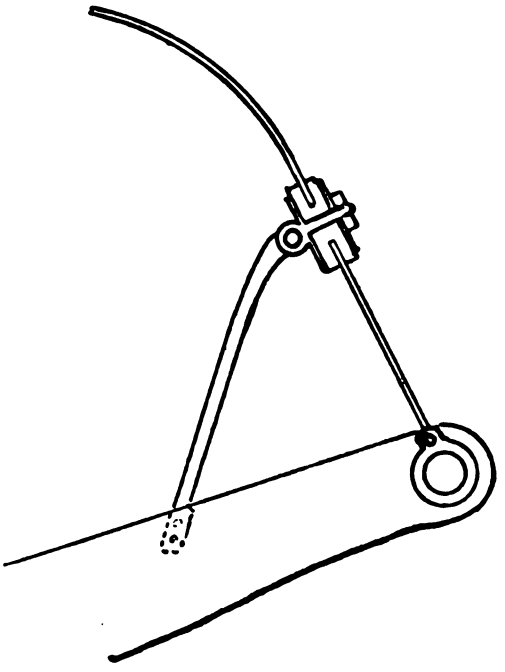

FIG. 17.
SHIELD SUPPORT.

The lower part of the shield is hung from the rear side of the axletree by short lengths of chain, which prevents it from being bent up if the wheels sink into the ground. It is secured by a clip to the under side of the axletree for travelling.

The front of the shield is covered with sheep-skin, with the wool on, dyed the same colour as the service uniform. This obviates the tendency of the shield to act as a heliograph when the sun strikes it. The Boers at Spion Kop covered the shields of their pom-poms with sacks to render them inconspicuous. (Von Wichman.)

It will be noted that the shield in this design is curved well back. This is because the enemy's bullets do not come in horizontally, but at angles of descent of 10 to 15° at medium ranges. The further back we get the shield the better the detachment will be protected. It is not desirable to have the shield higher than the wheels; but if more protection were required a folding flap at the top of the shield might be added.

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THE TRAIL EYE.

The French have adopted a spring trail eye, designed to ease the draught and reduce the travelling strains on the gun carriage. The same feature is found in the Bethlehem, St. Chamond, and Creusôt

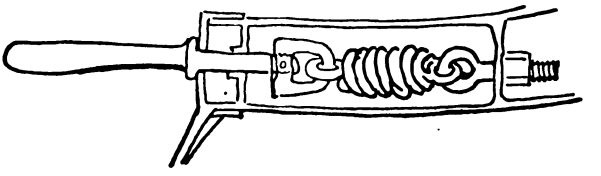

FIG. 13.
SKETCH OF SPRING TRAIL EYE.

equipments. No details of the French device are available, but the arrangement sketched in Fig. 13 will probably answer the purpose. This pattern of spring is used for lorries and heavy drays.

SEATS FOR DETACHMENT.

Since a Q.F. field gun, capable of firing 20 rounds per minute, is always accompanied into action by its ammunition wagon, it is no longer necessary to carry the whole of the gun detachment on the gun and limber. Three men on the gun limber, three on the wagon limber, and No. 1 on his horse, make a full detachment. The place of a Q.F. wagon in action is beside its gun, so that no men are required to carry ammunition up to the gun. This innovation enables us to make the gun heavier and more powerful without increasing the weight on the gun wheels. We save 80 lbs. on the two axletree seats and foot rests, and some 3 cwt. on the two gunners—say 3¼ cwt. in all. We are thus able to provide a shield weighing 150 lbs. and to make the gun 2¼ cwt. heavier than the old B.L. equipment without increasing the weight behind the team. The weight of the extra man on the limber will have to be allowed for by making the limber lighter and carrying fewer rounds.

ROUNDS ON THE GUN CARRIAGE.

In the new American equipment each gun carries four rounds, weighing with the tubes for carrying them about 80 lbs. This feature has not been embodied in the present design, for the following reason:

It is usually possible to bring a gun into action unseen by the enemy. But as soon as it opens fire the broad white flash of the smokeless powder catches the enemy's attention and draws his fire. If the gun opens fire before the wagon comes up, the wagon will have to drive up under fire. It is therefore generally desirable to wait (if necessary) for the wagon before opening fire. This being so, the extra four rounds on the gun would only be useful under exceptional circumstances.

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MINOR DETAILS OF CARRIAGE.

In the drawings of the buffer, a long screw will be noticed at the rear end. This is Krupp's device for putting the initial compression

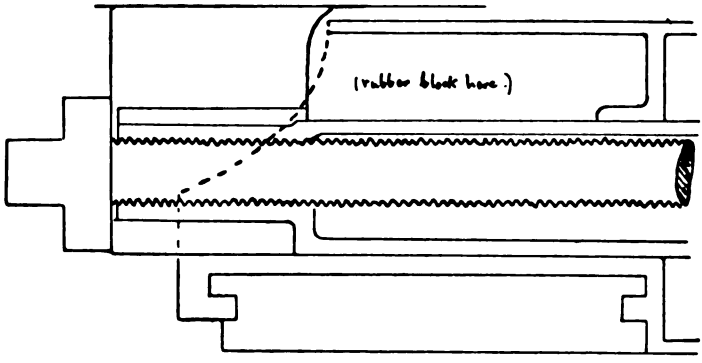

FIG. 6.

REAR END OF BUFFER AND COMPRESSOR SCREW.

on the running-up springs. The method of mounting the buffer and springs is as follows:—

Remove front plate of cradle; introduce the buffer with springs and parting plates, and press back by hand till the rear end of the buffer engages with compressor screw; wind up the screw by means of a handle till the buffer is home in the horn projecting downwards from the breech of the gun. The buffer is kept from turning by a wrench until it enters the horn, when a feather keeps it in the correct position. Finally, screw the front plate on to the piston rod and bolt it in its place.

TO FILL UP THE BUFFER.

The published drawings of the Krupp buffer do not show any filling plug. Krupp prefers to unscrew the whole stuffing-box without disturbing the packing. The following method (untried, and therefore open to suspicion) has been adopted in our present design. (See Fig. 3.)

In the front solid end of the hollow piston rod are bored two channels, one for the entrance of the oil or glycerine and the other for the escape of air. Both these channels are closed by one screw plug. In the normal position the inner ends of the channels are not within the buffer, but under the ring at the bottom of the gland. To fill up the buffer, slack the compressor screw three turns; this will allow the buffer to move forward up against the front plate of the cradle, and will bring the holes inside the buffer. Elevate the gun, take out the plug, and pour in the buffer liquid through the lower channel, while the air escapes through the upper channel; replace plug, and tighten the compressor screw.

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AMMUNITION.

A detailed description of the ammunition involves the consideration of a problem almost as serious as that of the design of the gun. Briefly, the gun is to fire fixed ammunition; the cordite charge is to be 20 oz. of cordite, Mark I., or a corresponding amount of cordite, tubular. Weight of fuzed shell, 15 lbs., to contain 310 bullets of 39 to the pound and a driving charge of 2½ oz. black powder, besides 2 oz. of coarse black powder among the bullets as a smoke-producer. The body of the shell is not intended to break up on explosion. This corresponds in effect to the latest Ehrhardt construction.

A percentage of high-explosive shell are to be carried; these are to be of the Krupp pattern, loaded with gun-cotton powder.

The fuze to be a double-banked Bazichelli fuze as used by Krupp and Ehrhardt. available as a time fuze up to 7,000 yards.

WEIGHTS.

We can now proceed to sum up the weights of the different parts. The gun, as has been said, weighs 782 lbs.; buffer casing and gland 79 lbs.; piston 16 lbs. and liquid 6¾ lbs.; springs and parting plates (by comparison with Ehrhardt) 70 lbs.* The cradle weighs by measurement 157.5 lbs., taking nickel-steel at approximately 500 lbs. per cubic foot. The trail, of ¼″ steel, weighs with traversing lever, spade, and all adjuncts 255 lbs.; this makes the lift at the trail handles 170 lbs. The elevating and laying gear, with radius bar, weigh 80 lbs.; traversing bed and stays 30 lbs.; telescope, clinometer and supports 10 lbs.; brake gear 80 lbs.; shield and stays 150 lbs. The wheels weigh about 200 lbs. each, if made of Woolwich pattern, though the American 4′ 8″ wheel is considerably lighter. The axle-tree with its bronze sleeve weighs 120 lbs.

Add 50 lbs. for bolts, nuts and details, such as the telescope case and the sheepskin, and we get a grand total of 2265 lbs., or 20½ cwt.

Some of the minor parts in this design have been made rather massive as compared with German practice; but even allowing for a reduction of a few pounds on the elevating gear and wheels, we shall barely get the weight of gun in action down to one ton, which is about two cwt. heavier than the average German 14½-pr. with M.V. of 1640 fs.

If a further reduction is desired it will have to be effected by reducing the diameter of the wheels, which not only reduces the weight of the wheels, but also the length and weight of the trail. Roughly speaking, one centimetre off the wheel means 5 kilos off the carriage, or one inch 27.5 lbs. At this rate, if we reduced the wheel from 4′ 8″ to 4′ 3″, the weight of the gun in action would be 1¼ cwt. less or say 18¾ cwt. But whether the big wheel is not worth the extra 1¼ cwt.

* Mr. Hadcock, of the E.O.C., who has been kind enough to criticise this essay, considers that the weight of 70 lb. allowed for springs and parting plates is insufficient in view of the extra length of recoil. If the weight be taken at 100 lb. this will bring the total weight of the gun and carriage up to 20¾ cwt.

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is another question. It must be remembered, moreover, that if we cut down the wheel we also (according to the above estimate) cut down the height of the shield, and to obtain equal protection we should have to add five inches to the top of the shield.

The writer is not vain enough to suppose that the design here worked out is the best possible construction for a field-gun. It is put forward principally as an academic design, intended to give officers an idea of the results which may be expected from a safe combination of proved and tested elements.

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RANGE TABLE FOR 15-pr. Q.F., MARK I.

This table may be taken as roughly representing the ballistics of any Krupp or Ehrhardt gun with the same muzzle velocity and weight of shell.

Charge { Weight 15.2 oz. / Nature ballistite in cords. — Muzzle velocity 1640 f.s. / Nature of mounting, Travelling Field.

Projectile { Nature Shrapnel shell, Mark Q.F. I. / Weight 14lb., 6oz. fuzed.

Barometer 29 inches.

Remaining velocity f.s.	Angle of descent.	Elevation		Range	50 per cent of rounds should fall in—			Time of flight.
					length	br'dth	height	
		Deg.	Min.	yards.	yards.	yards.	yards.	seconds.
..	..	..	1	100	..	..	..	..
..	..	..	8	200	..	..	..	..
..	..	..	15	300	..	..	..	..
..	..	..	22	400	..	..	..	..
1475	..	..	30	**500**	..	..	..	0.965
..	..	..	38	600	..	..	..	..
..	..	..	45	700	..	..	..	..
..	..	..	53	800	..	..	..	..
..	..	1	1	900	..	..	..	..
1325	..	1	9	**1000**	30	0.15	0.86	2.043
..	..	1	18	1100	..	..	..	..
..	1 in 30	1	26	1200	..	..	..	..
..	..	1	35	1300	..	..	..	..
..	1 in 25	1	44	1400	..	..	..	..
1199	..	1	53	**1500**	..	..	..	3.22
..	..	2	2	1600	..	..	..	..
..	1 in 20	2	12	1700	..	..	..	..
..	..	2	22	1800	..	..	..	..
..	..	2	32	1900	..	..	..	..
1094	..	2	43	**2000**	32	0.3	2	4.64
..	1 in 15	2	53	2100	..	..	..	..
..	..	3	4	2200	..	..	..	..
..	..	3	16	2300	..	..	..	..
..	1 in 12	3	28	2400	..	..	..	..
1021	..	3	40	**2500**	..	..	..	5.97
..	..	3	52	2600	..	..	..	..
..	1 in 10	4	4	2700	..	..	..	..
..	..	4	16	2800	..	..	..	..
..	..	4	20	2900	..	..	..	..
967	..	4	42	**3000**	36	0.6	4	7.56
..	1 in 8	4	56	3100	..	..	..	..
..	..	5	10	3200	..	..	..	..
..	..	5	24	3300	..	..	..	..
..	..	5	38	3400	..	..	..	..
912	..	5	52	**3500**	..	..	..	9.3
..	1 in 6	6	7	3600	..	..	..	..
..	..	6	22	3700	..	..	..	..
..	..	6	38	3800	..	..	..	..
..	..	6	55	3900	..	..	..	..
870	1 in 5	7	12	**4000**	40	1.1	8	10.93
..	..	7	29	4100	..	..	..	..
..	..	7	46	4200	..	..	..	..
..	..	8	4	4300	..	..	..	..
..	..	8	22	4400	..	..	..	..
830	1 in 4	8	40	**4500**	..	..	..	12.71
..	..	8	58	4600	..	..	..	..
..	..	9	17	4700	..	..	..	..
..	..	9	36	4800	..	..	..	..
..	..	9	55	4900	..	..	..	..

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Remaining velocity f.s.	Angle of descent	Elevation		Range	50 per cent of rounds should fall in—			Time of flight.
					length	br'dth	height	
		Deg.	Min.	yards.	yards.	yards.	yards.	seconds.
791	..	10	14	**5000**	45	1.8	14.2	14.7
..	..	10	33	5100	..	..	..	..
..	1 in 3	10	52	5200	..	..	..	..
..	..	11	12	5300	..	..	..	..
..	..	11	33	5400	..	..	..	..
753	..	11	54	**5500**	..	..	..	16.61
..	..	12	16	5600	..	..	..	..
..	1 in 2½	12	38	5700	..	..	..	..
..	..	13	0	5800	..	..	..	..
..	..	13	22	5900	..	..	..	..
721	..	13	44	**6000**	48	2.9	20.8	18.60
..	..	14	6	6100	..	..	..	..
..	..	14	28	6200	..	..	..	..
..	..	14	50	6300	..	..	..	..
..	..	15	12	6400	..	..	..	..
695	1 in 2	15	34	**6500**	..	..	..	20.68
..	..	15	55	6600	..	..	..	..
..	..	16	18	6700	..	..	..	..
..	..	16	40	6800	..	..	..	..
..	..	17	3	6900	..	..	..	..
668	1 in 1¾	17	26	**7000**	51	5.0	29	22.9

Note.—It is interesting to compare the accuracy figures with those of the 18pr. The comparative inaccuracy of the German gun at short ranges is to be ascribed to the spring of the long trail; the greater accuracy at long ranges to the better shape of the shell.

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TABLE OF SHRAPNEL BULLETS.

(85 lead to 15 antimony. Sp. Gr. 9.5.)

Weight to the pound.	Weight grammes approximate.	Nation.	Diameter, inches.	Ballistic Coefficient $\frac{w}{d^2}$	Lowest effective velocity for 60 foot-lbs.
29	15.7	Krupp Howitzers	.5774	.1034	335
28.4	16	" "	—	—	—
29.3	15.5	—	—	—	—
30.2	15	—	—	—	—
32.5	14	—	—	—	—
35	13	England (Howitzers)	.5415	.09740	368.6
36.4	12.5	Switzerland ..	.5341	.09608	376.4
38	12	France ..	.5268	.09477	384.1
39.5	11.5	—	—	—	—
41	11.1	—	—	—	—
41.3	11	Denmark ..	.5136	.09241	398.9
42	10.8	England ..	.5096	.09169	403.8
43	10.6	Russia ..	.5056	.09095	408.6
43.5	10.5	Holland, &c. ..	.5038	.09064	410.9
45	10	Germany, Italy, &c.	.4980	.08960	418.0
50	9.1	—	—	—	—
50.5	9	Austria ..	.4807	.08586	439.5

Remarks.

Shrapnel bullets are almost invariably made of an alloy of lead and antimony, varying from 9 lead and 1 antimony to 4 lead and antimony, which is the proportion given in the Treatise on Ammunition. The former composition is rather too soft, as the bullets tend to get flattened and to lose their shape on the shock of discharge; the latter is undesirably light. A good medium composition, used by most Continental nations, is 85 lead to 15 antimony. The best bullets are made by feeding a rod of metal into a machine which compresses it into bullets; these are about 1 per cent. denser than cast bullets, and their ballistic co-efficient 3 per cent. higher. The figures in the above table refer to cast bullets, but most foreign firms now use pressed bullets.

For ordinary work it will be found sufficient to take the first two significant figures of the ballistic coefficients given above.

If one bullet weighs x grammes, then there are $\frac{1000}{x}$ to the kilo or $\frac{1000}{x \times 2.2}$ to the pound.

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TABLE OF WEIGHT AND STRENGTH OF MATERIALS.

Material.	Specific Gravity.	Weight of 1 cubic foot. lbs.	Weight of 1 cubic inch. lbs.	Strength per square inch. Tensile tons.	Strength per square inch. Crushg. tons.
Aluminium, cast	2.56	160	0.092	—	—
Brass (3 copper to 1 zinc)	8.397	524	0.3	13.1	—
Aluminium bronze (copper 90. aluminium 10)	7.68	478	0.276	33	—
Aluminium zinc alloy (al. 85.5, zinc 13.75, copper 0.5 magnesium 0.25.)	3.18	198	0.115	17	—
Elswick bronze	8.2	510	0.296	28	—
Manganese bronze (75 copper, 5 tin, 20 manganese)	8.56	535	0.31	28	—
Phosphor bronze (89 copper, 10 tin, 1 phosphorus)	8.5	530	0.307	21	—
Silicon bronze (88 copper, 10 tin, 2 silicon)	8.9	555	0.32	35	25
Copper, sheet	8.78	548	0.316	13.4	—
Copper, wire	8.9	555	0.32	26	—
Gun metal (10 copper, 1 tin) ..	8.464	528	0.306	16.1	—
Iron, wrought, from	7.5	475	0.273	16	16
to	7.8	487	0.281	29	18
average	7.78	485	0.28	22	17
Iron, cast, from	7	437	0.252	6	36
to	7.6	474	0.273	13	64
average	7.23	451	0.26	7.3	48
Lead, cast	11.36	709	0.408	3.1	—
Magnalium (85 aluminium, 15 magnesium)	2.5	158	0.091	19	15
Mercury	13.596	849	0.491	—	—
Mixed metal (4 lead to 1 antimony)	9	562	0.324	—	—
Ditto (9 lead to 1 antimony) ..	10	624	0.36	—	—
Steel, mild 6% nickel	8	497	0.287	30	35
Steel, gun, 6% nickel (1)				49.4	50
Steel, nickel, hard for shields (2)				106.6	150
Ditto, for axletrees (3)				50.419	60
Steel wire or ribbon				120	—
Tungsten or wolfram	18.6	1161	0.6716	—	—
Zinc, cast	7	437	0.252	3.3	—

(1) Elastic limit 32.07 tons, final extension 18.6 %
(2) ,, 80 ,, ,, ,, 5.5 %
(3) ,, 47.688 ,, ,, ,, 23 %
} (Ehrhardt).

WEIGHT AND STRENGTH OF TIMBER.

Material.	Specific Gravity.	Weight of 1 cubic foot. lbs.	Weight of 1 cubic inch. lbs.	Strength per square inch. Tensile lbs.	Strength per square inch. Crushg. lbs.
Oak	0.93	57	0.0332	15000	8250
Ash	0.75	46.5	0.027	17700	9000
Elm	0.55	35	0.02	14000	10300
Fir	0.53	33.5	0.19	11000	5500

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TABLE OF GUN STEELS.

No. 1—Simple open-hearth steel, Messrs. Firth, Sheffield.
Carbon 0.48, Mn. 0.87, Sil. 0.17, Phos. 0.028, Sul. 0.035 per cent.
Static tests untreated: Yield 28 tons per square inch, break 48 tons per square inch, ultimate elongation before breaking 18%.
Ditto treated: Yield 45, break 60, stretch 12%.

No. 2—Armstrong nickel gun steel, treated.
Yield 40, break 49.4, stretch 24.5%.

No. 3—Firth's nickel gun steel, treated.
Yield 35, break 54, stretch 20%.

No. 4—German gun steel, 5% nickel, oil tempered.
Yield 33.7, break 50.4, stretch 21.5%.

No. 5—Firth's ditto.
Yield 38, break 56, stretch 18%.

No. 6—Ehrhardt's ditto, 6% nickel, oil tempered.
Yield 32, break 49.4, stretch 18.6%.

No. 7—Firth's ditto, 6% nickel.
Yield 34, break 52, stretch 18%.

No. 8—Bethlehem gun steel, treated.
Carbon 0.36, Mn. 0.81, Sil. 0.032, Phos. 0.026, Sul. 0.034, Nickel 3.33.
This is said to be 60-ton steel with 16% elongation.

No. 9—Armstrong nickel-chrome gun steel, treated.
Yield 59, break 63.5, stretch 18.5%.

No. 10—Armstrong chrome steel, treated.
Yield 65, break 87.4, stretch 12.5%.

No. 11—Schneider chrome gun steel, said to contain 1.75% chromium.
Yield 37, break 56.4, stretch 19.8%.

No. 12—Hadfield's special gun steel, treated.
Yield 49.5, break 60, stretch 23.5%.

No. 13—Willans & Robinson's chrome-vanadium gun steel, annealed.
Carbon 0.38, Sil. 0.065, Mn. 0.47, Chromium 1.267, Vanadium 0.187, Phos., Sul. and Arsenic under 0.04.
Yield 39.3, break 53.1, stretch 23.5%.

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TABLE OF GUN STEELS.—*Continued.*

No. 14—Krupp spring steel, tempered.
Yield 89, break 137.

No. 15—Ehrhardt ditto.
Yield 120, break 53.1, stretch 3%.

No. 16—Cammell Laird ditto, said to contain molybdenum.
Yield 107, break 123, stretch 2%.

No. 17—Chrome-vanadium spring steel, oil tempered.
Carbon 0.44, Sil. 0.173, Mn. 0.837, Chromium 1.044, Van. 0.186, Phos., Sul. and Arsenic under 0.04.
Yield 53.9, break 80.3, stretch 12.5%.

No. 18—Ehrhardt axletree steel, non-weldable.
Yield 47.7, break 50.4, stretch 23%.

No. 19—Firth's ditto, nickel-chrome, untreated.
Yield 43, break 55, stretch 25%.
Ditto, oil-tempered: yield 51, break 62, stretch 22%.

No. 20—Ehrhardt's nickel-tungsten shield steel, untreated.
Yield 80, break 105, stretch 5.5%.

No. 21—Bethlehem nickel-tungsten shield steel.
Carbon 0.29, Mn. 0.09, Sil. 0.035, Phos. 0.012, Sul. 0.05, Tungsten 3%.

PRICES.

These vary according to the specification, but the following may be taken as a guide:—

Carbon gun steel, untreated	...	...	£20 per ton
Nickel ,, ,,	...	...	£30 ,,
Nickel-chrome ,,	...	...	£30 ,,
Vanadium ,, ,,	...	...	£33 ,,
Carbon spring steel, treated	...	...	£25 ,,
Vanadium ,, ,,	...	...	£40 ,,

NOTE.—The above gun-steel tests refer to test pieces cut from large forgings under the same conditions as those approved by the English, German and American Governments. Fancy results may be obtained from small experimental forgings, but these are unreliable.

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Page 336.—Ehrhardt spring steel breaks at 142 tons.

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TABLE OF ANGLES.

EXPRESSED BY THE RELATION OF HEIGHT TO BASE.

Approximate only.

1	degree	is equal	to 1	in 57.25
2	,,	,,	,,	25
3	,,	,,	,,	19
4	,,	,,	,,	14
5	,,	,,	,,	11.5
6	,,	,,	,,	9.5
7	,,	,,	,,	8.25
8	,,	,,	,,	7.25
9	,,	,,	,,	6.5
10	,,	,,	,,	6
11	,,	,,	,,	5.15
12	,,	,,	,,	4.75
13	,,	,,	,,	4.33
14	,,	,,	,,	4
15	,,	,,	,,	3.75
16	,,	,,	,,	3.5
17	,,	,,	,,	3.25
18	,,	,,	,,	3
19	,,	,,	,,	2.88
20	,,	,,	,,	2.75
25	,,	,,	,,	2.15
30	,,	,,	,,	1.75
35	,,	,,	,,	1.43
40	,,	,,	,,	1.20
45	,,	,,	,,	1

Five degrees is equal to an inch in a foot nearly.

TABLE OF SLOPES AND ANGLES.

A slope of	Corresponds to an angle of
1 in 1	45°
1 in 1½	33° 50′
1 in 1¾	29° 41′
1 in 2	26° 34′
1 in 2½	21° 50′
1 in 3	18° 26′
1 in 4	14° 3′
1 in 5	11° 19′
1 in 6	9° 29′
1 in 8	7° 8′
1 in 10	5° 43′
1 in 12	4° 45′
1 in 15	3° 50′
1 in 20	2° 52′
1 in 25	2° 18′
1 in 30	1° 54′

For small angles, one minute subtends one inch at 100 yards, or one foot at 1200 yards, or one yard at 3600 yards.

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CONVERSION OF MEASURES.

(Chiefly based on data contained in Col. Noble's Useful Tables.)

LENGTH.

Metric to English.

Metres.	Yards.	Feet.	Inches.
1	1.0936	3.2809	39.37
2	2.1873	6.5618	78.74
3	3.2809	9.8427	118.11
4	4.3745	13.1236	157.48
5	5.4682	16.4045	196.85
6	6.5618	19.6854	236.22
7	7.6554	22.9663	275.60
8	8.7491	26.2472	314.97
9	9.8427	29.5281	354.34

English to Metric.

Yds.	Metres.	Feet.	Metres.	Ins.	Centimetres.
1	0.91438	1	0.30479	1	2.5400
2	1.82877	2	0.60959	2	5.0799
3	2.74315	3	0.91438	3	7.6199
4	3.65753	4	1.21918	4	10.1598
5	4.57192	5	1.52397	5	12.6998
6	5.48630	6	1.82877	6	15.2397
7	6.40068	7	2.13356	7	17.7797
8	7.31507	8	2.43836	8	20.3106
9	8.22945	9	2.74315	9	22.8596

Metric Table of Length.

Millimetres.
10 = 1 centimetre.
100 = 1 decimetre.
1000 = 1 metre.

Metres.
10 = 1 decameter.
100 = 1 hectometer.
1000 = 1 kilometre,

EXPLANATION.—To convert any number from one measure to the other, take the values of the different multiples of 10 by shifting the position of the decimal point, and add together. Thus, find the number

of yards in 2354 metres (see cols. 1 and 2).	of feet in 12.4 metres (see cols. 1 and 3).	of inches in 30·5 centimetres (see cols. 1 and 4). Note, 1m. = 100 cm.	of metres in 1026 yards (see cols. 5 and 6).	of metres in 1742 feet (see cols. 7 and 8).	of centimetres in 17.72 ins. (see cols. 9 and 10).
metres. yards.			yards. metres.	feet. metres.	inches. cms.
2000 = 2187.3	metres. feet.		1000 = 914.38	1000 = 304.79	10 = 25.400
300 = 328.09	10 = 32.809	cms. inches.	20 = 18.29	700 = 213.36	7 = 17.780
50 = 54.68	2 = 6.562	30.0 = 11.811	6 = 5.49	40 = 12.19	0.7 = 1.778
4 = 4.37	0.4 = 1.312	.5 = 0.197		2 = 0.61	0.02 = 0.051
∴ 2354 = 2574.44	∴ 12.4 = 40.683	∴ 30.5 = 12.008	∴ 1026 = 938.16	∴ 1742 = 530.95	∴ 17.72 = 45.009

NOTE.—If a table of conversion is not at hand, an approximation to the English equivalent in inches of a distance measured in centimetres may be obtained by multiplying by 0.4: thus 30.5 cm. multiply by 0.4, and we have 12.2 inches; the real equivalent as shown above is 12.008 inches.

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FEET EXPRESSED AS METRES.

Ft.	0	1	2	3	4	5	6	7	8	9
	Metres	Metres	Metres	Metres	Metres	Metres	Metres	Metres	Metres	Metres
0	·000	0·3048	0·6096	0·9144	1·2192	1·5239	1·8287	2·1335	2·4383	2·7431
1	3·0479	3·3527	3·6575	3 9623	4·2671	4·5719	4·8767	5·1815	5·4863	5·7911
2	6·0359	6·4006	6·7055	7·0102	7·3150	7·6198	7·9246	8·2294	8·5342	8·8390
3	9·1438	9·4486	9·7534	10·052	10·363	10·668	10·972	11·277	11·582	11·887
4	12·192	12·496	12·801	13.106	13·411	13·716	14·020	14·325	14·630	14·935
5	16·239	15·544	15·849	16·154	16.459	16·763	I7·068	17·376	17·678	17·983
6	18·287	18·592	18·897	19·202	19·507	19·811	20·116	20 421	20·726	21·031
7	21·335	21·640	21·945	22·250	22·555	22 859	23·164	23·469	23·774	24·079
8	24·383	24·688	24·993	25·298	25·602	25·907	26·212	26·517	26·822	27.126
9	27·431	27·736	28·041	28·346	28·651	28·955	29·260	29·565	29·870	30·174
10	30·479	30·784	31·089	31·394	31·698	32·005	32·308	32·613	32·918	33.222

METRES EXPRESSED AS FEET.

Me.	0	1	2	3	4	5	6	7	8	9
	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
0	·000	3·2809	6·5618	9·8427	13·123	16·404	19·685	22·966	26·247	29·528
1	32·808	36·090	39·371	42·651	45·932	49·213	52·494	55·775	59·056	62·337
2	65·618	68·899	72·179	75·461	78·741	82·022	85·303	88·584	91·865	95·146
3	98·427	101·71	104·99	108·27	111·55	114·83	118·11	121·39	124·67	127·96
4	131·24	134·52	137·80	141·08	144·36	147·64	150·92	154·20	157·48	160·76
5	164·04	167·33	170·61	173·89	177·17	180·45	183·73	187 01	190·29	193·57
6	196·85	200·13	203·42	206·70	209·98	213·26	216·54	219·82	223·10	226·38
7	229·66	232·94	236·22	239·51	242·79	246·07	249·35	252·63	255·91	259·19
8	262·47	265·75	269·03	272·31	275.60	278·88	282·16	285 44	288·72	292·00
9	295·28	298·56	301·84	305·12	308·40	311·69	314 97	318·25	321·53	324·81
10	328·09	331·37	334·65	337·93	341·21	344·49	347·78	351·06	354·34	357·62

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MILLIMETRES AND THEIR EQUIVALENTS IN INCHES.

Mm.	Inches	Mm.	Inches	Mm.	Inches	Mm.	Inches	Mm.	Inches	Mm.	Inches
1	·0394	18	·7087	35	1·3780	52	2·0473	69	2·7166	86	3·3859
2	·0787	19	·7480	36	1·4173	53	2·0866	70	2·7559	87	3·4252
3	·1181	20	·7874	37	1·4567	54	2·1260	71	2·7953	88	3·4646
4	·1575	21	·8268	38	1·4961	55	2·1654	72	2·8347	89	3·5040
5	·1968	22	·8561	39	1·5354	56	2·2047	73	2·8740	90	3·5433
6	·2362	23	·9055	40	1·5748	57	2·2441	74	2·9134	91	3·5827
7	·2756	24	·9449	41	1·6142	58	2·2835	75	2·9528	92	3·6221
8	·3150	25	·9843	42	1·6536	59	2·3228	76	2·9922	93	3·6614
9	·3543	26	1·0236	43	1·6929	60	2·3622	77	3·0315	94	3·7008
10	·3979	27	1·0630	44	1·7323	61	2·4016	78	3·0709	95	3·7402
11	·4331	28	1·1024	45	1·7717	62	2·4410	79	3·1103	96	3·7796
12	·4724	29	1·1417	46	1·8110	63	2·4803	80	3·1496	97	3·8189
13	·5118	30	1·1811	47	1·8504	64	2·5197	81	3·1890	98	3·8583
14	·5512	31	1·2205	48	1·8898	65	2·5591	82	3·2284	99	3·8977
15	·5906	32	1·2498	49	1·9291	66	2·5984	83	3·2677	100	3·9370
16	·6299	33	1·2992	50	1·9685	67	2·6378	84	3·3071		
17	·6693	34	1·3386	51	2·0079	68	2·6772	85	3·3465		

TO CONVERT METRIC UNITS TO BRITISH, AND VICE VERSÂ.

Kilo-metres		Eng. miles	Square Kilo-metres		Sq. Eng. miles	Metres		Yards	Kilogrs		lbs. Avoir	Litres		Gal-lons.
1·609	1	0·621	2·592	1	0·386	0·914	1	1·094	0·457	1	2·20	4·54	1	0·22
3·219	2	1·243	5·184	2	0·772	1·829	2	2·187	0·907	2	4·41	9·09	2	0·44
4·828	3	1·863	7·776	3	1·158	2·743	3	3·281	1·361	3	6·61	13·63	3	0·66
6 438	4	2·486	10·368	4	1·544	3·658	4	4·374	1·814	4	8·82	18·17	4	0·88
8·047	5	3·107	12·960	5	1·930	4·572	5	5·468	2·268	5	11·02	22·72	5	1·10
9·656	6	3·728	15·522	6	2·316	5·486	6	6·562	2·722	6	13·23	27·26	6	1·32
11·265	7	4.350	18·144	7	2·702	6·401	7	7·655	3·175	7	15·43	31·80	7	1·54
12·879	8	4·971	20·736	8	3·088	7·315	8	8·749	3·629	8	17·64	36·35	8	1·76
14·484	9	5·592	23·328	9	3·474	8·229	9	9·843	4·082	9	19·84	40·89	9	1·98
16·093	10	6·214	25·920	10	3·860	9·144	10	10·936	4·536	10	22·05	45·43	10	2·20
32·186	20	12·428	51·840	20	7·720	18·288	20	21·873	9·072	20	44·09	90·87	20	4·40
48·279	30	18·641	77·760	30	11 580	27·432	30	32·809	13·608	30	66·14	136·30	30	6·60
64·373	40	24·855	103·680	40	15·440	36·576	40	43 745	18·144	40	88·18	181·74	40	8·80
80·466	50	31·069	129·600	50	19·300	45·719	50	54·682	22·679	50	110·23	227·17	50	11·00
96·559	60	37·283	155·520	60	23·160	54·863	60	65·618	27·215	60	132·28	272·61	60	13·20
112·652	70	43·497	181·440	70	27·020	64·007	70	76·554	31·752	70	154·32	318·04	70	15·40
128·746	80	49·710	207·360	80	30·880	73·151	80	87·491	36·288	80	176·37	363·48	80	17·60
144·839	90	55·924	233·380	90	34·740	82·295	90	98·427	10·823	90	198·42	408·91	90	19·80
160·932	100	62·138	259·200	100	38·601	91·438	100	109·363	45·359	100	220·46	454·35	100	22·01

Example.—10 miles = 16.093 kilometres, or 10 kilometres = 6.214 miles.
Similarly 6 lbs. = 2.722 kilogrammes, or 6 kilogrammes = 13.23 lbs.
1 square decimetre = 15.5 square inches.
1 cubic decimetre = 61 cubic inches.

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WEIGHT.

English to Metric.

Kilogrammes	Tons.	Pounds Avoirdupois.	Grains Troy.
1	.000984	2.2046	15432.3
2	.001968	4.4092	30864.7
3	.002953	6.6139	46297.0
4	.003937	8.8185	61729.4
5	.004921	11.0231	77161.7
6	.005905	13.2277	92594.1
7	.006889	15.4323	108026.4
8	.007874	17.6370	123458.8
9	.008858	19.8416	138891.1

English to Metric.

Tons.	Metric tons or milliers.	Pounds Avoirdupois.	Kilogrammes.	Grains Troy.	Grammes.
1	1.016	1	0.4536	1	.0648
2	2.032	2	0.9072	2	.1296
3	3.048	3	1.3608	3	.1944
4	4.064	4	1.8144	4	.2592
5	5.080	5	2.2680	5	.3240
6	6.096	6	2.7216	6	.3888
7	7.112	7	3.1751	7	.4536
8	8.128	8	3.6287	8	.5184
9	9.144	9	4.0823	9	.5832

Metric Table of Weight.

Milligrammes.
10 = 1 centigramme.
100 = 1 décigramme.
1000 = 1 gramme.

Grammes.
10 = 1 décagramme.
100 = 1 hectogramme.
1000 = 1 kilogramme.

Kilogrammes.
10 = 1 myriagramme.
100 = 1 quintal.
1000 = 1 millier, or metric ton.

EXPLANATION.—To convert any number from one measure to the other, take the values of the different multiples of 10 by shifting the position of the decimal point and add together. Thus, find the number

of tons in 35 milliers (see cols. 1 and 2).	of pounds in 56.3 kgms. (see cols. 1 and 3).	of grains in 120 grammes (see cols. 1 and 4).	of milliers in 38 tons (see cols. 5 and 6).	of kilogrammes in 68 pounds (see cols. 7 and 8).	of grammes in 85 grains (see cols. 9 and 10).
milliers. tons.	kgms. lbs.	grammes. grains.	tons. milliers.	lbs. kgs.	grains. grammes.
30 = 29.53	50 = 110.231	100 = 1543.23	30 = 30.48	60 = 27.216	80 = 5.184
5 = 4.92	6 = 13.228	20 = 308.65	8 = 8.13	8 = 3.629	5 = 0.324
∴ 35 = 34.45	0.3 = 0.661	∴ 120 = 1851.88	∴ 38 = 38.61	∴ 68 = 30.845	∴ 85 = 5.508
	∴ 56.3 = 124.120				

NOTE.—7000 grains troy = 1 pound avoirdupois.

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PRESSURE.

Metric and Atmospheric to English.

Kilogrammes per sq. cm.	Pounds per square inch.	Tons per square inch.	Atmospheres.	Pounds per square inch.	Tons per square inch.
1	14.223	.00635	1	14.7	.00656
2	28.446	.01270	2	29.4	.01313
3	42.668	.01905	3	44.1	.01969
4	56.891	.02540	4	58.8	.02625
5	71.114	.03175	5	73.5	.03281
6	85.337	.03810	6	88.2	.03938
7	99.560	.04445	7	102.9	.04594
8	113.783	.05080	8	117.6	.05250
9	128.005	.05715	9	132.3	.05906

English to Metric and Atmospheric.

Pounds per sq. inch.	Kilogrammes per sq. cm.	Atmospheres.	Tons per square inch.	Kilogrammes per sq. cm.	Atmospheres.
1	.07031	.068	1	157.49	152.38
2	.14062	.136	2	314.99	304.76
3	.21093	.204	3	472.48	457.14
4	.28124	.272	4	629.97	609.52
5	.35155	.340	5	787.47	761.91
6	.42186	.408	6	944.96	914.29
7	.49217	.476	7	1102.45	1066.67
8	.56248	.544	8	1259.95	1219.05
9	.63279	.612	9	1417.44	1371.43

EXPLANATION.—To convert any number from one measure to the other, take the values of the different multiples of 10 by shifting the position of the decimal point, and add together. Thus, find the number

of pounds per square inch in 32.1 kilogrammes per square centimètre (see cols. 1 and 2).

kgs. per sq. cm.		lbs. per sq. in.
30	=	426.68
2	=	28.45
0.1	=	1.42
∴ 32.1	=	456.55

of tons per square inch in 3210 kilogrammes per square centimètre (see cols. 1 and 3).

kgs. per sq. cm.		tons per sq. in.
3000	=	19.05
200	=	1.27
10	=	0.06
∴ 3210	=	20.38

of tons per square inch in 3254 atmospheres (see cols. 4 and 6).

atmospheres.		tons per sq. in.
3000	=	19.69
200	=	1.31
50	=	0.33
4	=	0.03
∴ 3254	=	21.36

of kilogrammes per square centimètre in 15 lbs. on the square inch (see cols. 7 and 8).

lbs. per sq. in.		kgs. per sq. cm.
10	=	0.7031
5	=	0.3516
∴ 15	=	1.0547

of kilogrammes per square centimètre in 18.3 tons per square inch. (see cols. 10 and 11).

tons per sq. in.		kgs. per sq. cm.
10	=	1574.9
8	=	1259.95
0.3	=	47.25
∴ 18.3	=	2882.1

of atmospheres in 14.6 tons per square inch (see cols. 10 and 12).

tons per sq. in.		atmospheres.
10	=	1523.8
4	=	609.5
0.6	=	91.4
∴ 14.6	=	2224.7

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ENERGY.

Metric to English.		*English to Metric.*	
Metre-tons.	Foot-tons.	Foot-tons.	Metre-tons.
1	3.2291	1	0.3097
2	6.4581	5	0.6194
3	9.6872	3	0.9291
4	12.9162	4	1.2388
5	16.1453	5	1.5484
6	19.3743	6	1.8581
7	22.6034	7	2.1678
8	25.8324	8	2.4775
9	29.0615	9	2.7872

EXPLANATION.—To convert any number from one measure to the other, take the values of the different multiples of 10 by shifting the position of the decimal point, and add together. Thus, find the number

of foot-tons in 4367 metre-tons (see cols. 1 and 2).		of metre-tons in 3592 foot-tons (see cols. 3 and 4).	
metre-tons.	foot-tons.	foot-tons.	metre-tons.
4000 =	12916.2	3000 =	929.1
300 =	968.72	500 =	154.84
60 =	193.74	90 =	27.87
7 =	22.60	2 =	0.62
∴ 4367 =	14101.26	∴ 3592 =	1112.43

NOTE.—1000 metre-tons is called a dinamode in Italy.

The Metrical System.

In the metrical system, the metre is intended to be (and is very nearly) the ten-millioneth part of the distance on the surface of the earth from the equator to the pole; the cube of a decimetre, or of the tenth part of a metre, is the unit of capacity, and is called a litre, and the weight of a litre of distilled water at its greatest density is the unit of weight called a kilogram.

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logs	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
·01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	2	2	2	2
·02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	2	2	2	2
·03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	2	2	2	2
·04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	2	2	2	2	2
·05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	2	2	2	2	2
·06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	2	2	2	2	2
·07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	2	2	2	2	2
·08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	2	2	2	3	3
·09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	2	2	2	3	3
·10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	2	2	2	3	3
·11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	3	3
·12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	2	2	2	2	3	3
·13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	2	2	2	3	3	3
·14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	2	2	2	3	3	3
·15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	2	2	2	3	3	3
·16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	2	2	2	3	3	3
·17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	2	2	2	3	3	3
·18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	2	2	2	3	3	3
·19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	2	2	3	3	3	3
·20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	2	2	3	3	3	3
·21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	3	3	3	3
·22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	3	3	3	3
·23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	3	3	4	4
·24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	3	3	4	4
·25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	3	3	4	4
·26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	4	4
·27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	4	4
·28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
·29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
·30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
·31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
·32	2089	2 94	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
·33	2137	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
·34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
·35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
·36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
·37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
·38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
·39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
·40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
·41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
·42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
·43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
·44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
·45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
·46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
·47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	6	6
·48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
·49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6

logs	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
·51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
·52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
·53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
·54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
·55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
·56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
·57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
·58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
·59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
·60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	7	7	8
·61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
·62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
·63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
·64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
·65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
·66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
·67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
·68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
·69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
·70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
·71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
·72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
·73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
·74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
·75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
·76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
·77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
·78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
·79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
·80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
·81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
·82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
·83	6761	6776	6792	6808	6823	6839	6855	6871	6887	69 2	2	3	5	6	8	9	11	13	14
·84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
·85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
·86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
·87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
·88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
·89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
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·91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
·92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	16	17
·93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
·94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
·95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
·96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
·97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
·98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
·99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

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No	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
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12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
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89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
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98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	4	4

$\log \pi = 4971$; $\log 2g = 1.8089$; $\log 2240 = 3.3502$; $\log 2g \times 2240 = 5.1591$; $\log \dfrac{1}{2g \times 2240} = \bar{6}.8409$.

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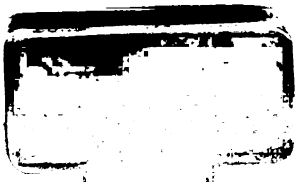

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